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Institute and Related Activities

Air-Break Magnetic Blow-Outs

For Contactors and Circuit Breakers Both A-C. and D-C.

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Review of the Subject.—*Magnetic blow-outs have been used in contactors, circuit breakers and controllers for many years for rupturing both a-c. and d-c. power circuits, but their commercial use, particularly on alternating current has been largely confined to relatively low voltages. Oil circuit breakers and switches have been generally used for rupturing high-voltage a-c. power circuits, and their development has reached a high state of perfection. The air break has the advantage of avoiding the possibilities which attend the use of any inflammable material—like oil, with its possible gasification and explosion on heavy short circuits.*

While there are many different types of magnetic blow-outs this paper deals largely with the "individual" type, in which a blow-out coil is connected in series with each pair of current-rupturing contacts, since it is with this type that most of the progress and studies have been made in recent years.

Contactors and circuit breakers with the "individual" type of blow-out are now used almost exclusively in the main d-c. power circuits of the 1500 and 3000-volt d-c. railway systems. Oil circuit breakers have been tried for this service, but they are rather unsatisfactory because there is no periodic zero point in the current wave at which the oil can form an insulating seal between contacts. The oil under d-c. arc conditions carbonizes rapidly and involves the possible danger from explosive gases.

Recently the use of magnetic blow-out contactors on a-c. circuits has been extended to moderately high voltage and capacity. Short-circuit tests on a 6600-volt, 26,700-kv-a. alternator are described towards the end of the paper. During these three-phase tests the air-break magnetic blow-out contactors successfully ruptured 17,500 amperes, the full short-circuit current, at 5500 volts. This is 170,000 kv-a., three-phase. The maximum asymmetrical peak current through the contacts during this test was 67,500 amperes, but during a 2500-volt short-circuit test this peak current reached 80,000 amperes. Oscillograph records of the voltage and current in each phase are shown and also illustrations of the arcs.

The contactors used were rated at 5000 volts, 3000 amperes, but they successfully ruptured a circuit of 9000 volts, 3500 amperes. The oscillographic records and illustrations of this test are shown in Figs. 25 and 26. Current-rupturing tests at 2300 amperes and 3500 amperes normal voltage are also shown for comparison in Figs. 22 to 24. In all of the tests the circuit was ruptured within the first half cycle after the tips started to part, indicating the effectiveness of this type of blow-out.

The arrangement of the current-carrying and magnetic blow-out parts are shown in Fig. 15. The main current is carried through solid copper contacts mounted at the back. The auxiliary contacts in the arc chute and the blow-out coils carry current only during the time the circuit is being ruptured. These coils with their attending arcing horns are cut into the circuit in succession, so as to obtain the strongest possible final magnetic field without undue arcing at the contact tips and across the terminals of the coils when they are introduced into the circuit. Several arc suppressor plates are provided in each half of the arc chute which increases the cooling surface, and on heavy short circuits split the arc into a number of multiple paths. See Fig. 10.

A brief description is given in the first part of the paper of a typical form of the "individual" type magnetic blow-out as used in contactors and circuit breakers, and photographs of a number of contactors for various a-c. and d-c. voltages are reproduced. Attention is directed to the tests with accompanying illustrations of successive positions of the arc in the chute taken with a high-speed camera, from which some interesting data were obtained on arc characteristics. The arc was photographed in its movement every three-thousands of a second. The time between pictures in the familiar motion picture camera is sixty-two-thousandths of a second. These tests bring out the effectiveness, in rupturing the circuit of the arc suppressor plates and narrow arc chutes.

CONTENTS

THEORY OF THE MAGNETIC BLOW-OUT

It is a well-known fact that when a conductor of length l carries a current of i amperes in a magnetic field of density of B maxwells per square centimeter, the force F in kg. per centimeter length tending to move the conductor across the field is

$$F = 10.2\,B\,i\,l\,10^{-8}\text{ kg.}$$

In the same way, when an arc forms between switch contacts which open in a magnetic field, the resulting arc stream will be subjected to the above force and will move across the field and lengthen until the voltage between the contacts is no longer able to maintain a current flow and the circuit is ruptured. It is the function of the magnetic blow-out, which is essentially an electromagnet, to set up the magnetic field over the area within which it is desired to rupture the circuit. To be most effective the direction of the lines of force in the field should be perpendicular to the axis of the arc stream.

The direction of movement of the arc stream is the same as for a conductor moving in a magnetic field, and may be readily determined by Fleming's rules or by the right-hand screw rule. In common with flexible conductors, the arc stream always moves, and in addi-

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tion lengthens, so as to include the maximum number of ines of force. The blow-out coil must, therefore, be

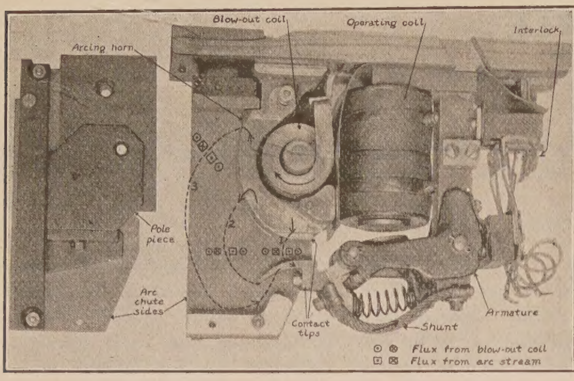

FIG. 1—600 VOLT ARMATURE TYPE RAILWAY CONTACTOR

Part of arc chute is removed and placed to one side more clearly to illustrate the magnetic blow-out. When current flows in blow-out coil as indicated by arrow the flux through the core in the blow-out coil is away from reader as indicated by a cross in a circle. This flux returns through arc chute area towards reader as indicated by a dot in a circle. When the contact tips open the arc stream (1) forms and the flux encircling this arc stream strengthens the blow-out flux at the back as indicated by a dot in a circle and a dot in a rectangle and weakens it in front as indicated by a dot in a circle and a cross in a rectangle. As the arc stream always moves from the strong towards the weak field, it will move from position 1 through positions 2 and 3, etc., until the circuit is ruptured.

wound in such a direction that its flux strengthens the flux encircling the arc stream in the rear of the moving arc stream and consequently weakens it in the front.

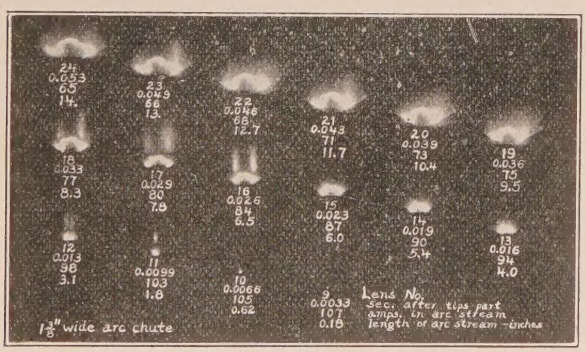

FIG. 2

Sixteen successive photographs of arc streams taken with a high-speed camera having twenty-four lenses arranged on four slanting rows of six each. In this figure the arc was ruptured 0.06 sec. after the last exposure. The lenses were uncovered in succession by a single focal plane shutter which moved across the plate at such a speed as to expose each point of the arc chute approximately 0.0016 sec. The time between pictures is approximately 0.00328 sec. The successive pictures bring out in particular the changes in the arc stream during a time interval of 0.00328 sec. The delineations on the original flims were sufficiently distinct so that the length of arc in each picture could be measured. This length, together with the arc stream current and the time after the contactor tips parted, are indicated for each picture. The inside dimensions of the blow-out coil which can be seen in Figs. 4 and 5 were approximately 10 in. by 21 in. Only the inside area of this blow-out coil was effective in lengthening the arc as the flux is in the wrong direction on the outside of the coil. The maximum length of the arc within the blow-out coil was approximately 35 in.

The circuit was high in inductance. There were five d-c. motor fields in series. Width of chute 1 3/8 in., current about 100 amperes, voltage 650 d-c. This figure is to be compared to Fig. 3 in which the arc chute was 3/8 in. wide.

Fig. 1 shows a typical 600-volt railway contactor having the "individual" type of blow-out, which illustrates the above points. One side of the arc chute is removed to show more clearly the general arrangement of parts. Arrows indicate an assumed direction of current flow through the current-carrying parts and the direction of the resultant lines of force are indicatd by the conventional signs. It will be noted that the direction of the flux in the iron core of the blow-out coil is away from the

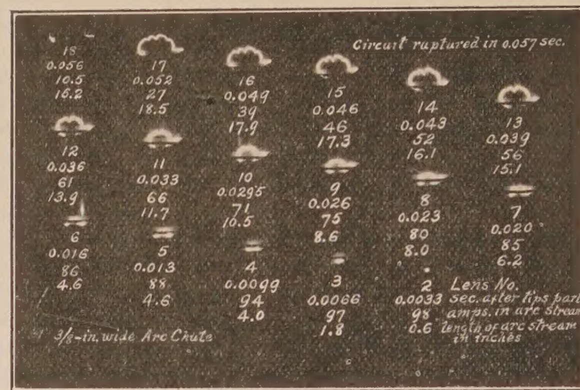

FIG. 3

Sixteen successive photographs of the arc stream taken with a high-speed camera (see details of camera in caption of Fig. 2). Conditions: Same as in Fig. 2 except that the width of arc chute is now 3/8 in. whereas in Fig. 2 it was 1 3/8 in.

reader. This flux, after being distributed by the iron pole pieces returns through the arc chute area, strengthening the flux encircling the arc stream at the back and weakening it in front causing the arc to be moved successively through positions 1, 2, 3 until the circuit is ruptured. If the direction of current is reversed through the contactor, the direction of all lines of force will also be reversed, so that the blow-out flux

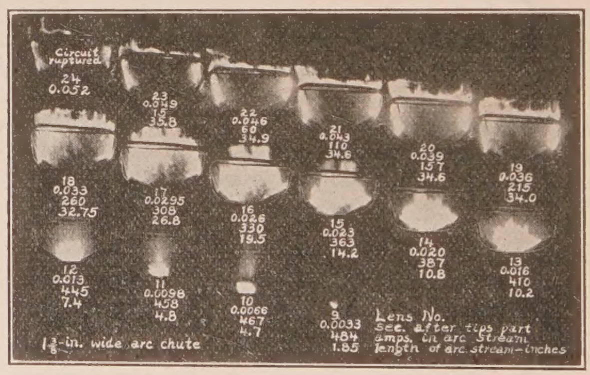

FIG. 4

Sixteen successive photographs of the arc stream, taken with a high-speed camera (see details of the camera in the caption of Fig. 2). Conditions: The current now is 500 amperes where it was only 100 amperes in Fig. 2. The arc chute width is 1 3/8 in. This figure is to be compared with Fig. 2 for the effect of variation in current, and with Fig. 5, of the same value of current of 500 amperes, for the effect of the decrease in arc chute width.

will still strengthen the field back of the arc stream, causing the arc to be moved through positions 1, 2, 3 as before. The arc chute sides which are made of arc-resisting insulation, help to cool the arc and maintain the axis of the arc stream perpendicular to the blow-out flux.

Arc Characteristics

Some very interesting studies of arc stream characteristics were made some time ago by Mr. F. O. McMillan under the writer's general direction. Figs. 2, 3, 4 and 5 show representative illustrations taken by a high-speed camera invented by Mr. Chester Lichtenberg. This camera has 24 lenses arranged in four

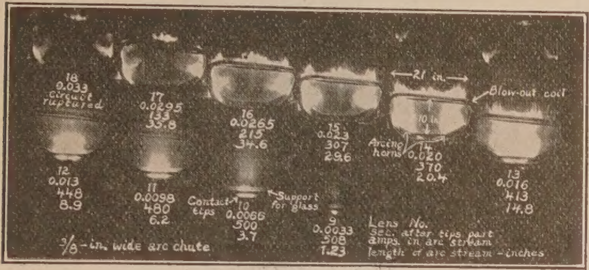

Fig. 5

Ten successive photographs of the arc stream taken with a high-speed camera (see details of the camera in the caption of Fig. 2). Conditions: Same as Fig. 4 except that the arc chute width is now only 3/8 in. where it was 1 3/8 in. in the case of Fig. 4. The current is again 500 amperes. To compare the effects of currents at 500 amperes and 100 amperes refer to Fig. 3, which has the same width of arc chute as Fig. 5.

slanting rows of six each. The lenses are all served by a single focal plane shutter which first uncovers the lens in the lower right hand corner then the next lens to the left across the bottom row, and so on through the other rows, each row starting at the right. The speed of the shutter was adjusted so that the time interval

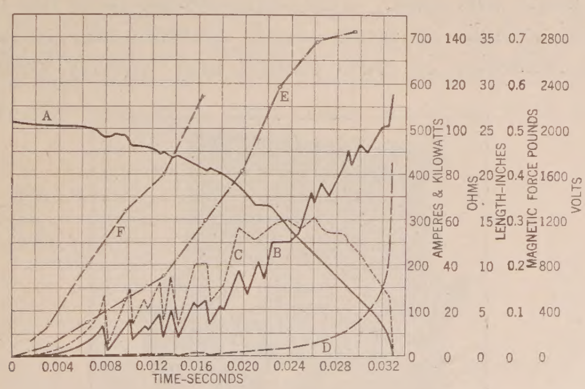

Fig. 6—Arc Characteristics

The data for these six curves were obtained from oscillographic records taken in connection with the current-rupturing test recorded in Fig. 5. The width of arc chute was 3/8 in. and the flux density approximately 2.5 lines per square inch per ampere.

Curve *A*—Arc current vs. time in fraction of a sec.
Curve *B*—Arc potential vs. time in fraction of a sec.
Curve *C*—Arc power vs. time in fraction of a sec.
Curve *D*—Arc resistance vs. time in fraction of a sec.
Curve *E*—Arc length vs. time in fraction of a sec.
Curve *F*—Magnetic force on arc vs. time in fraction of a sec.

between each picture was 0.00328 second, and each point of the arc stream was exposed approximately 0.0016 second. In order to photograph the arc, one of the arc chute sides was made of glass, and special blow-out coils were wound giving an approximately uniform flux within the area in which it was desired to rupture the circuit. Oscillographic records were taken of the current and voltage of the circuit, simultaneously with the high-speed photographs. Fig. 6, gives curves plotted from these records, which show the complete arc characteristics when rupturing a 500-ampere, 650-volt inductive circuit in an arc chute ⅜ in wide under the influence of a magnetic blow-out

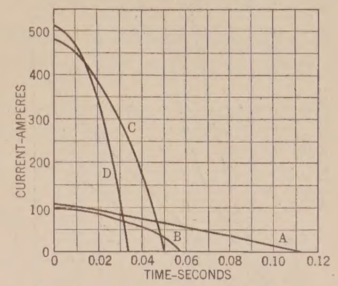

Fig. 7—Four Curves of Time vs. Current of Arcs in Figs. 2, 3, 4 and 5, Respectively

Curve *A* corresponds to arc stream in Fig. 2, *B* to Fig. 3 *C* to Fig. 4 and *D* to Fig. 5. The width of arc chute for curves *A* and *C* was 1 3/8 in. and for *B* and *D* 3/8 in. These curves are intended to illustrate the effectiveness of both narrow slots and suppressor plates in the arc chutes. See Fig. 10.

giving a flux density of approximately 2.5 lines per square inch per ampere.

The illustrations in Figs. 2, 3, 4 and 5 bring out in particular the changes in the arc stream during a time interval of 0.00328 second, when rupturing an inductive circuit at currents ranging from 100 to 500 amperes at 650 volts. A summary of the corresponding time characteristics of the arc are plotted in Fig. 7.

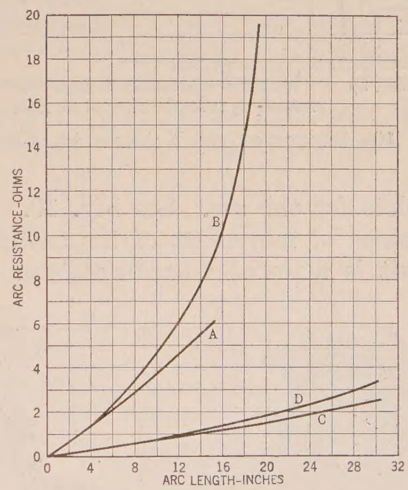

Fig. 8—Four Curves of Length vs. Resistance of Arcs in Figs. 2, 3, 4 and 5, Respectively

Curve *A* corresponds to arc stream in Fig. 2, *B* to Fig. 3, *C* to Fig. 4 and *D* to Fig. 5. The width of arc chute for curves *A* and *C* was 1 3/8 in. and for *B* and *D* 3/8 in.

The Narrow Arc Chute

Attention is directed to a comparison of Curves *A* and *B* and of *C* and *D* of Fig. 7. The conditions under which the two sets were taken were the same, except the width of the arc chute for curves *A* and *C* was 1⅜ in. and for *B* and *D*, ⅜ in. The narrow arc chute is a recent development and has contributed very mate-

rially towards the successful rupturing of high-capacity a-c. and d-c. power circuits.

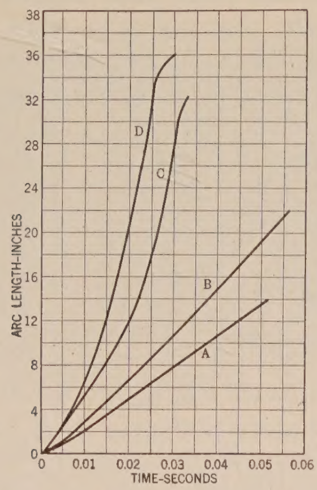

Fig. 9—Four Curves of Time vs. Length of Arcs in Figs. 2, 3, 4 and 5, Respectively

Curve A corresponds to arc stream in Fig. 2, B to Fig. 3, C to Fig. 4 and D to Fig. 5. The width of arc chute for curves A and C wa 1 3/8 in. and for B and D 3/8 in.

The effect of the narrow arc chute is usually obtained by adding one or more arc suppressor plates to the standard arc chute. This gives a number of multiple

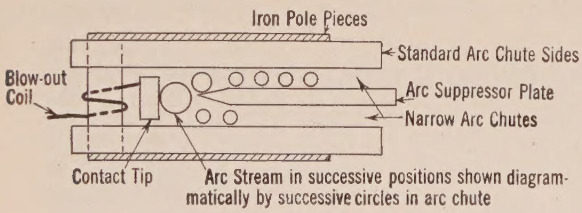

Fig. 10—Sketch of the Narrow Arc Chute

paths or slots for the arc. See Fig. 10. Each slot is in the plane of movement of the switch contacts and the exit is materially narrower than the width

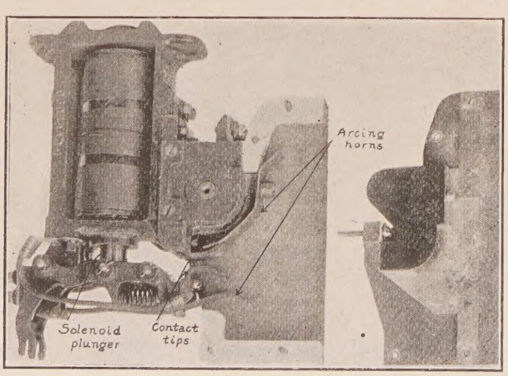

Fig. 11—600-Volt, 425-Ampere D-C. Plunger Type Railway Contactor

Part of arc chute removed and placed to one side more clearly to show contact tips and arcing horns.

of the switch contacts and the space within which the arc is formed. These slots reduce the cross section of the arc stream and serve to increase the resistance for a given length. The arc suppressor plates provide additional cooling surface to the arc, and maintain the axis of the arc stream perpendicular to the blow-out flux. In wide arc chutes, the arc stream has a tendency to wander from one side of the chute to the

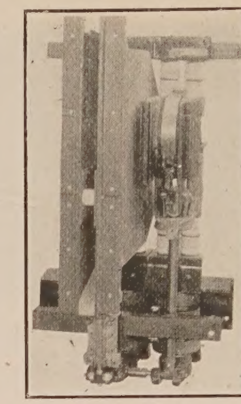

Fig. 12—3000-Volt, 215 Ampere D-C. Contactor

Two units are used in series for 3000 volts. One arc chute removed to show parts.

other so that at times its axis is nearly parallel to the blow-out flux.

It will be noted in both tests where the narrow arc chute was used, the circuit was ruptured in approximately one-half the time of the tests where the wider arc chute was used. This approximate ratio has been found to hold for much higher currents and voltages. The reduction in cross section and quicker opening

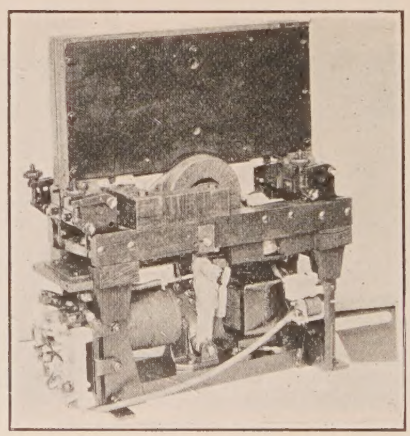

Fig. 13—High-Speed Circuit Breaker

is plainly evident from a comparison of the time and current printed under each arc stream in Figs. 2 and 3. The narrow chute is particularly effective in connection with high-speed direct-current circuit breakers where it is desirable to rupture the circuit in a few thousandths of a second.

Fig. 8 shows the relation between arc resistance and arc length for both the wide and narrow arc chutes, and Fig. 9 shows the rapidity with which the arc

lengthened under the influence of the magnetic blow-out in both widths of the chutes.

In making the above tests on arc chracteristics, it was not possible to rupture very large amounts of power on account of the danger of breaking the glass arc-chute side used for taking the photographs. Current rupturing tests have been made, however, with magnetic blow-out air-break contactors up to 6000 volts d-c. and 9000 volts a-c. and the indications are that still higher voltages can easily be ruptured successfully.

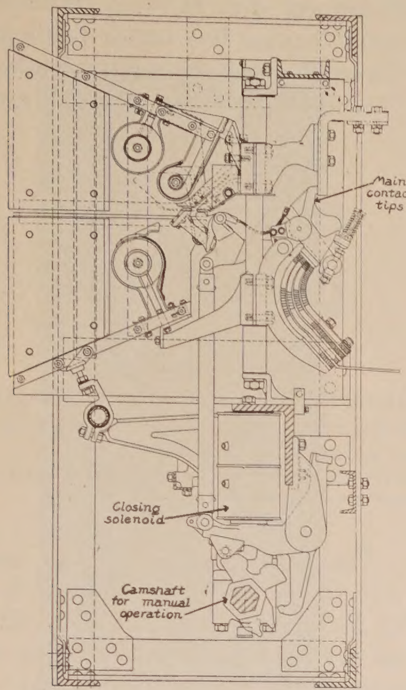

Fig. 14—3500-Volt, 3500-Ampere A-C. Contactor (Closed)

Contactor may be closed either manually, by means of the cam shaft, or electromagnetically by means of the solenoid.

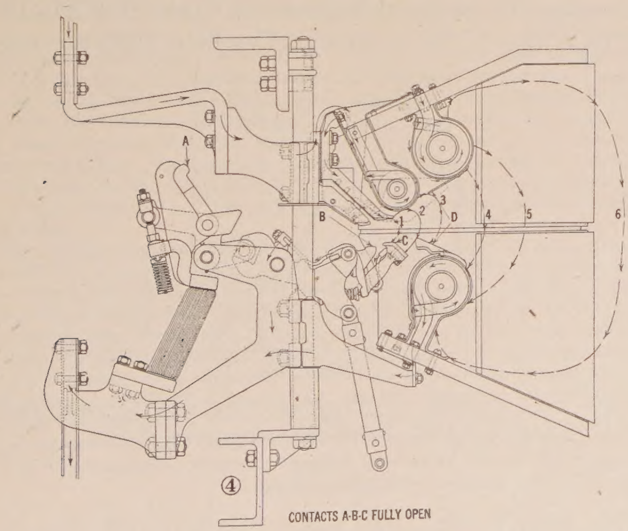

Fig. 15—5000-Volt, 3000-Ampere A-C. Contactor (Open)

This contactor was developed primarily for controlling the main motor circuits of the new 180,000-horse power Battle Cruisers for the U. S. Government. Very exhaustive tests were made before and after the final designs were completed. The results amply met expectations as to the suitability of this type of contactor, not only for ship propulsion, but also for power station service.

Typical A-C. and D-C. Contactors

Figs. 11, 12, 13, 14 and 15 show some typical forms of a-c. and d-c. contactors and circuit breakers for various voltages on which tests and data are presented in this paper.

Flux Density in Arc Chutes

Fig. 16 shows the average flux density curves in the arc chute of typical 600-volt and 3000-volt contactors and also of a 3000-volt high-speed circuit breaker. It will be noted that a much higher flux density is used for the 3000-volt contactors and circuit breaker than for the 600-volt contactor. Many tests and experiments have been made to determine the correct flux density for each type; but the inductance, particularly of railway circuits is so variable that it is difficult to select a flux density to best suit all conditions. In general, a flux density in the arc chute which will cause the current to be reduced at a *rate approximately equal to the initial rate of rise when normal voltage is applied to the circuit*, appears to give about the best average result. See Fig. 17. If the flux density in a particular design is too high, the voltage across the arc increases beyond the breakdown point of the insulation of the arc chute sides and the arc reestablishes a number of times as clearly shown by Fig. 18. Curve *A* of this figure shows the rupture of a 600-volt, 1500-ampere inductive circuit by a magnetic blow-out in which the average flux density in the arc chute at

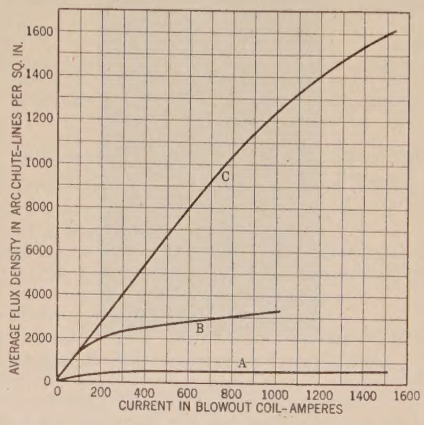

Fig. 16—Arc Chute Flux Density vs. Current in Blow-out Coil

Curve *A*—For 600-volt, 425-ampere contactor.
Curve *B*—For 3000-volt, 215-ampere contactor.
Curve *C*—For 3000-volt high-speed circuit breaker.

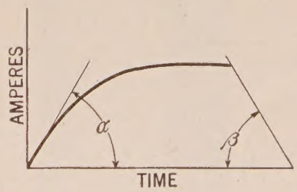

Fig. 17—Theoretical Current-Rupturing Test

Curve showing current decrement to give best average results when opening a circuit. Angle β should be approximately equal to angle α so that the inductive voltage when opening the circuit will not exceed the line voltage.

1500 amperes was approximately 600 lines per sq. in., and Curve *C* approximately the same current and voltage under the influence of a blow-out of approximately 1500 lines per sq. in. Due to the reestablishments it

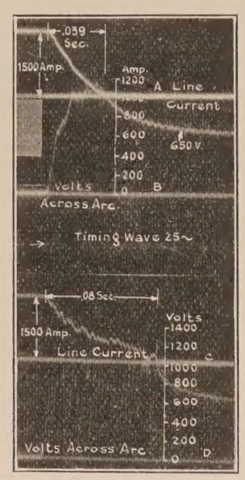

FIG. 18—OSCILLOGRAPHIC RECORDS OF CURRENT-RUPTURING TESTS

Illustrating the effect of high and low flux densities in the arc chute. Two motor fields were used in series for reactance.

The flux density in the arc chute of the contactor used when rupturing the current shown by Curve *C* was too high for this particular design, being approximately three times that of the contactor when rupturing the current shown by Curve *A*. The current and voltage fluctuations of the arc are very marked on Curves *C* and *D* while there are practically no sudden fluctuations of current and voltage where the low flux density was used as shown by the two upper curves *A* and *B*.

required more than twice the time to rupture the circuit with the blow-out giving the stronger magnetic field. The shape of the arcing horns and the size of the arc chute have a material bearing, however, and by properly proportioning these parts, relatively high

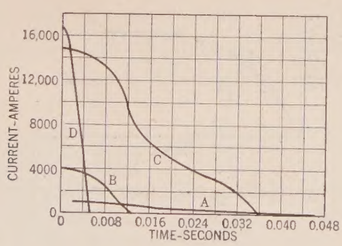

FIG. 19—FOUR CURVES OF TIME VS. CURRENT ILLUSTRATING 600-VOLT D-C. CURRENT-RUPTURING TESTS

Curve *A*—Test with five motor fields in series for reactance using contactor shown in Fig. 11.

Curve *B*—Test with four motor fields in parallel for reactance using contactor shown in Fig. 11.

Curve *C*—Test with no external reactance. Contactor used shown in Fig. 11.

Curve *D*—High-speed circuit breaker. Practically no external reactance.

densities may be used when it is desirable to rupture the circuit very quickly, as in the high-speed circuit breaker. The principle limitation is then the maximum inductive kick the other apparatus in the circuit will stand.

CURRENT RUPTURING TESTS AT 600 VOLTS D-C.

Curves *A*, *B* and *C* of Fig. 19 plotted from oscillograph records, show typical current-rupturing tests on a 600-volt, 425-ampere d-c. railway contactor. Curve *A* is for a circuit having five motor fields in series for reactance, Curve *B* with four motor fields in parallel and Curve *C* is for a circuit of practically no external

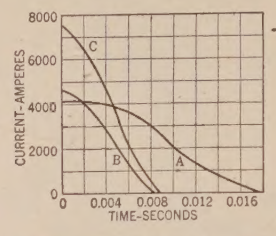

FIG. 20—THREE CURVES OF TIME VS. CURRENT ILLUSTRATING 3000-VOLT D-C. CURRENT-RUPTURING TESTS

Curve *A*—For contactors shown in Fig. 12.

Curves *B* and *C*—For high-speed circuit breaker. See Fig. 13. No external reactance used during tests.

inductance. The same contactor was used for all three tests and the strength of blow-out is shown by Curve *A*, Fig. 16. Curve *D* is for a 600-volt, 5000-ampere, d-c. high-speed circuit breaker having a blow-out of approximately the same strength as shown by Curve *C* of Fig. 16. It will be noted that the current of Curve *D*, Fig. 19 was reduced at a very fast rate, averaging approximately 3,500,000 amperes per second.

CURRENT RUPTURING TESTS AT 3000 VOLTS D-C.

Fig. 20 shows typical current-rupturing tests at 3000 volts, d-c. Curve *A* is representative of the performance of the contactor shown in Fig. 12 and the strength of the magnetic blow-out is shown by Curve *B* of Fig.16. Curves *B* and *C* are representative of a 1500-ampere,

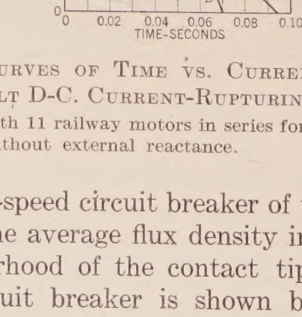

FIG. 21—TWO CURVES OF TIME VS. CURRENT ILLUSTRATING 6000-VOLT D-C. CURRENT-RUPTURING TESTS

Curve *A*—Test with 11 railway motors in series for reactance.

Curve *B*—Test without external reactance.

3000-volt, high-speed circuit breaker of the type shown in Fig. 13. The average flux density in the arc chute in the neighborhood of the contact tips of a typical high-speed circuit breaker is shown by Curve *C* of Fig. 16.

CURRENT RUPTURING TESTS AT 6000 VOLTS D-C.

Curves *A* and *B* of Fig. 21 are plotted from oscillograph records of current-rupturing tests on a 6000-volt

250-ampere, d-c. contactor. In the test represented by Curve *B* practically no external inductance was used in the circuit while in the tests represented by Curve *A* the fields of 11 railway motors were used in series in the circuit.

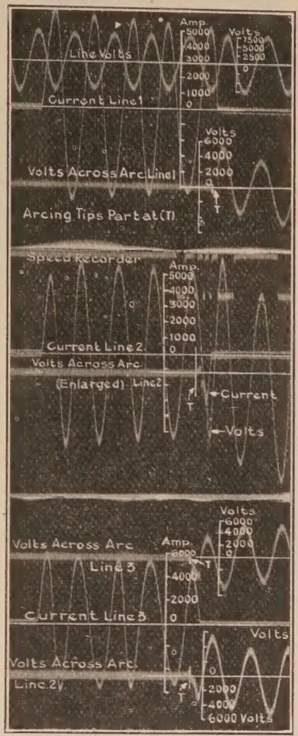

Fig. 22—Oscillographic Records of a 5000-Volt 3500-Ampere, Three-Phase, 25-Cycle Current-Rupturing Test

One contactor as shown in Fig. 15 was connected in each phase. Line voltage initial 5700 volts, under load 5000 volts. First cycle after opening 5280 volts. Line current 3630 amperes effective. External resistance 0.683 ohm per phase. External reactance 0.197 ohm per phase.

Three separate oscillograms operating in synchronism were used for this test, each oscillogram having records of three vibrators. The vibrators in the upper oscillogram are numbered 1, 2 and 3, in the middle oscillogram 4, 5 and 6, and in the lower oscillogram 7, 8 and 9. Vibrator No. 2 shows the current in line 1 and vibrator No. 3 shows the voltage across the terminals of the contactor in this line. Vibrator No. 5 shows the current in line 2 and vibrators No. 6 and No. 9 show the voltage across the terminals of the contactor. Vibrator No. 6 records the same voltage as vibrator No. 9, except on an enlarged scale. Vibrator No. 8 records the current in line 3 and vibrator No. 7 the voltage across the terminals of the contactor in this line.

The voltage between lines 1 and 3 is recorded by vibrator No. 1. Vibrator No. 4 gives a record of the mechanical movement of the contact tips, from which the exact instant the arcing tips parted was determined. This point is recorded on the zero line in each oscillogram by the letter *T*. The circuit was closed by a separate three-phase switch. The current continued for about 4¼ cycles before the arcing tips of the contactor started to part. As soon as the tips parted the voltage across the arc begins to rise. Within one-half cycle after the tips part the line current is reduced to zero and does not reestablish, and the voltage across the contact tips starts to adjust towards normal *Y* voltage. For schematic diagram of connections see Fig. 22*A*.

Current Rupturing Tests At 5000 Volts A-C.

Recently the possibility of using magnetic blow-out contactors for rupturing high power a-c. circuits has been recognized and the design and construction has already been completed on contactors rated up to 5000 volts. Fig. 14 shows a typical 3500-volt, 3500-ampere contactor and Fig. 15 a 5000-volt, 3000-ampere contactor, both of which are equipped with a magnetic blow-out of rather novel construction. One side of the arc chute was removed in both contactors to more clearly show the construction. The 3500-volt contactor is shown in the closed position and the 5000-volt one in the open position. It should be noted that the main current is carried through heavy copper contacts,

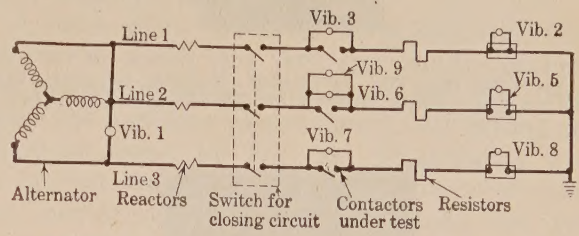

Fig. 22A—Schematic Diagram of Connections for Alternating Current Rupturing Tests

Vibrator 1—Voltage between lines 1 and 3.
Vibrator 2—Current in line 1.
Vibrator 3—Voltage across terminals of contactor in line 1 (arc voltage).
Vibrator 4—Records the position and speed of movement of the contacts of the three contactors under test.
Vibrator 5—Current in line 2.
Vibrator 6—Same voltage as vibrator 9 except enlarged deflections.
Vibrator 7—Voltage across terminals of contactor in line 3.
Vibrator 8—Current in line 3.
Vibrator 9—Voltage across terminals of contactor in line 2.
See Figs. 22 to 28, inclusive.

marked *A* in Fig. 15, which are located at the back of the contactor. There are no loops in the path of the main current-carrying parts which might tend to cause overheating on alternating current or to blow the contacts apart on heavy short circuits. The contacts *B* and *C*, located in the arc chute, carry practically no current during normal operation and consequently may be made light and inexpensive.

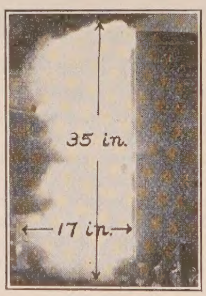

Fig. 23—Showing the Luminous Vapors of the Arc when Rupturing 5000-Volts, 3500-Amperes, A-C.

The vapors of the three phases blend in one impression on the photographic plate.

When the contactor, Fig. 15 is closed, all three sets of contacts marked *A*, *B* and *C* are in contact. As the contactor opens the tips *A* first part, transferring the main current to contacts *B* located in the arc chute. Further movement towards the open position starts contacts *B* open, transferring the current to contacts *C* and cutting the small blow-out coil at the back of the arc chute into the circuit, as indicated by the arrows. The front tips *C* part next and the arc stream marked

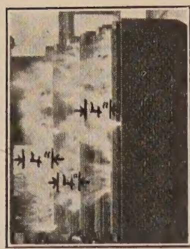

Fig. 24—Showing the Luminous Vapors of the Three Separate Arcs when Rupturing 5000-Volts, 2300-Amperes, A-C.

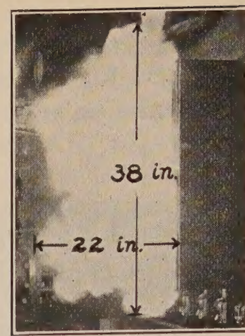

Fig. 26—Extent of the Vapors from the Arc Beyond the Arc Chute when Rupturing 9000-Volts, 3500-Amperes, A-C.

The photographic plate was exposed during the whole time the gases were being expelled and the vapors from all three phases are superposed.

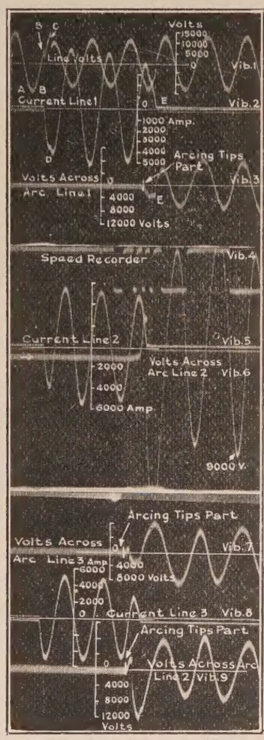

Fig. 25—Oscillograms of a Three-Phase Test at 25 Cycles of Over-Voltage but Normal Current Rating

One contactor as shown in Fig. 15 was connected in each phase. Line voltage, initial 9700 volts, under load 7400 volts. First cycle after opening 8700 volts. Line current 3350 amperes effective. External resistance 1.08 ohms per phase. External reactance 0.197 ohm per phase.

The story of the oscillographic records is as follows: There are three separate oscillograms. Each oscillogram has records of three vibrators. Each of the oscillograms has a record of the normal load current and the voltage across the arc of the corresponding phase. In the upper oscillogram the load current is given for line 1 by vibrator 2 and the voltage across the arc by vibrator 3. On open circuit this is *Y* voltage. In the middle oscillogram the relations are the same for the load current and voltage across the arc of line 2. In the lower oscillogram the current of line 3 is given by vibrator 8 and the corresponding voltage across the arc is given by vibrator 7. In this oscillogram, vibrator 9 repeats the voltage across the arc of line 2 which is given in the oscillogram just above by vibrator 6 with a magnified scale.

Vibrator 1 of the upper oscillogram gives the voltage from line 1 to line 3 and vibrator 4 in the middle oscillogram gives a record of contacts which record the movement of several mechanical parts.

Starting with the record of normal line-to-line voltage at the point marked *A* in the upper oscillogram, the load current in lines 1 and 2 starts at the point marked *B* (shown by a sudden drop in the voltage) and the current in line 3 starts at the point marked *C* which causes a sudden drop again in the voltage and a corresponding change in the load current of line 1 at *D*. Since the neutral of the generator was not grounded, it required the closure of two contacts to start the load current and therefore there are only two disturbances in the main voltage wave. The current in line 1, vibrator 2, continues 2½ cycles before the arcing tips part. Vibrator 3 shows the beginning of the voltage across the arc at this point. Since the current is extinguished in one-half cycle of arc, as shown by the cessation of wave in vibrator 2 at *E*, the voltage immediately thereafter starts in its adjustment to the normal condition of *Y* voltage from line to ground. This same explanation applies to the other two oscillograms of the other phases.

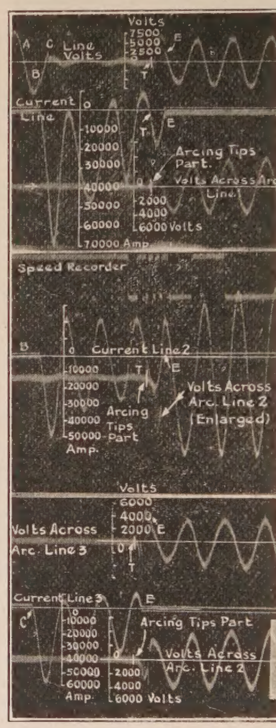

Fig. 27—5000-Volt Short-Circuit Test on 26,700 Kv-a. Alternator

One contactor as shown in Fig. 15 connected in each phase. Initial open circuit voltage 5700 volts. First cycle after opening, 3980 volts. Average line current, at the instant the contactors opened 16,600 amperes effective.

The same arrangement of oscillographs and vibrators was used in this test as described in the caption under Figs. 22 and 22A. This test differs from the normal load test recorded in Fig. 22 in that the external resistance and reactance were removed from the circuit resulting in a dead short circuit on the alternator.

Referring to the record of line voltage in the upper oscillogram, there is a sudden momentary reduction in voltage at the point marked *B* which is due to two of the contacts of the three-phase circuit closing switch making contact ahead of the third, applying a single-phase short circuit through lines 1 and 2 for about 0.008 sec. At the point marked *C* on the line voltage and current waves line 3 was closed establishing the full three-phase short circuit. The short-circuit current was on the contactors for slightly more than three cycles before the arcing tips parted. The instant at which the arcing tips parted is indicated by the letter *T* on all three oscillograms. The circuit was completely ruptured within one-half cycle after the tips parted as evidenced by the cessation of current at the point marked *E*. All the voltage waves are slightly ragged during the time the circuit is being ruptured, that is between points *T* and *E*.

The current in line 1 reached the maximum possible asymmetrical value as the first cycle was displaced entirely on one side of the zero line. The maximum peak value of current in this line was 67,700 amperes. The maximum peak current in line 2 was 48,000 amperes and in line 3, 56,000 amperes. The average effective current in the three lines at the instant the tips parted was about 16,600 amperes.

1 in Fig. 15 forms between the tips. This arc stream is now under the influence of the rear blow-out coil and begins to move rapidly towards the front of the chute. When in position 2, the arc stream touches the lower arcing horn D introducing the lower blow-out coil in the circuit. Further movement into position 3 introduces the upper arcing horn D and the upper blow-out coil into the circuit. All three blow-out coils are now in series and the arc moves rapidly around the arcing horns D through positions 4, 5, and 6 until the arc is stretched out to a sufficient length to rupture the circuit. It will be observed that the arc chute is divided into two parts with the slot between the two halves giving an air gap to more effectively isolate the upper and lower contact tips when the contactor is open. With this arrangement, it is possible to design for a much higher voltage than would otherwise be possible, as most insulations which will stand the high temperature arc streams are usually relatively poor insulators.

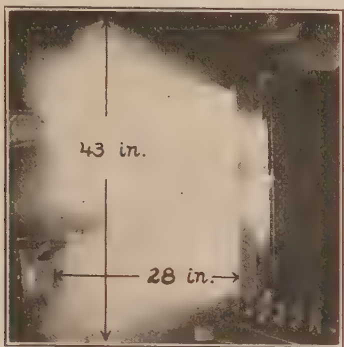

Fig. 28—Showing the Extent of the Luminous Vapors Beyond the Arc Chute when Rupturing Short-Circuit Currents of Fig. 27

As in Figs. 23 and 25, the arcs from the three phases blend in one impression on the photographic plate.

Fig. 22 shows the current and voltage phenomena in all three phases, while rupturing 3500 amperes at 5000 volts, 25 cycles, with the 5000-volt, 3000-ampere, a-c. contactors, shown in Fig. 15. Fig. 23 shows the distance the arc is visible beyond the arc chute. Fig. 24 shows the distance the arc is visible beyond the edge of chutes when rupturing 5000 volts, 2300 amperes under the same conditions. The arcs from all three contactors can be distinguished in the 2300-ampere test, but in the 3500-ampere tests the luminous vapors from the three phases blend in one impression on the photographic plate. The plates were exposed during the whole time the circuits were being ruptured so that the photographs are of value only as showing the maximum distance the luminous vapors were forced beyond the arc chutes by the magnetic blow-out. If the photographs had been taken with a very high-speed multifilm camera the results would have been more like those of Fig. 3.

Fig. 25 shows records of the same contactors, which are rated at 5000 volts, 3000 amperes, rupturing approximately 9000 volts, 3500 amperes, and Fig. 26 shows the extent of the arc. The circuit was ruptured very satisfactorily in this test and there was no evidence that the ultimate rupturing capacity of the contactors had yet been reached.

A dead short circuit on a 26,700-kv-a., 25-cycle alternator, which was very successfully ruptured by the above contactors is shown in Fig. 27. The distance the luminous vapors were forced beyond the arc chute is shown by Fig. 28. Attention is directed to the fact that the maximum asymmetrical peak current carried by the main contacts during this test was approximately 67,500 amperes and that the r. m. s. current (a-c. and d-c. components) at the instant the contactor tips started to part was 17,400 amperes for phase 1, 14,650 amperes for phase 2, and 17,800 amperes for phase 3. The current in each phase was completely ruptured within a ½ cycle after the arcing tips started to part. The fact that the current did not reestablish in the second half cycle after the tips parted indicates the effectiveness of this type of magnetic blow-out.

Conclusions

While the tests and data presented in this paper are on a-c. and d-c. current-rupturing apparatus of only moderately high-voltage rating, the fundamental principles described for the magnetic blow-outs are applicable to much higher voltages. The tests and experience indicate that we have not yet approached the limit of the alternating voltage or current which may be successfully ruptured repeatedly in the air. In fact we anticipate that within a reasonable period of time the principal of the air-break magnetic blow-out will be extended to cover applications in a-c. power circuits of the higher voltages. There is no question of the ability of the magnetic blow-out to meet the future requirements of high voltage d-c. power circuits.

It is probable that the River Rhone hydroelectric project as originally conceived may undergo serious modifications by the exclusion for the present of the phases of navigation and irrigation, leaving the harnessing of the Rhone essentially an undertaking for derivation of hydroelectric energy. The utilization of the vast resources of power resident in the Rhone envisages in itself a very large operation, requiring years and the expenditure of much money, but returns from the sale of hydroelectric energy will be assured.

It is not possible to predict the exact decisions to be reached in advance of the sessions of the Commission, the National Company, and the various parties interested, but there seems a strong probability that the majority of those interested will desire to push the immediate project for development of hydroelectric power, postponing the navigation and irrigation projects until actual results have been obtained.

COMPARISON OF RESEARCH SPIRIT IN AMERICA AND IN EUROPE*

Learning was in disfavor in Russia until the eighteenth century, when an attempt was made to improve the educational system by importing academicians from Germany. But they had no foundation on which to build. To secure men of the trained minds it was necessary to have universities; but when universities were founded, they were unable to get students because there were no high schools. It was, therefore, necessary to inaugurate a system of high schools. Finally it dawned on someone that in order to supply the high schools it was necessary to establish primary schools.

To some degree the understructure for the supply of research talent is lacking in this country. When Professor Karapetoff came to this country he began to select subjects for research. In 1909 he privately printed a list which was sent to colleges as containing suitable subjects for student's work. In 1916 he presented before the American Institute of Electrical Engineers a paper, containing an enlarged list of topics on electrical research. This came to the attention of the *Electrical World*. Its editor suggested a section in that magazine on "Research." This section has been running regularly since March 1917. In editing this section Professor Karapetoff was brought into touch with all varieties of investigators. From this contact he was able to obtain a general picture of research in this country.

In this country it is necessary to speak of "money value" of research. This is not true in other countries. One would not speak of the money value of painting, music, sculpture. Why should it be necessary in research, which requires a similar love of nature and its laws? One of the great difficulties encountered is the wide diversity of investigation and development falling under the name of "research"; for example, the smallest improvement in a machine is called research, as is also the Einstein theory.

Professor Karapetoff likened the findings of researchers to dots on a chart, which record experimental observations. What we lack in this country is research men of the calibre to place dots out in spaces where little is known. Organization, for which we seem particularly fitted, can fill the gaps, but it cannot place the pioneer dots.

Experimental research may be practical or theoretical. Non-experimental research may also be practical, as for example, Dr. Steinmetz's mathematical investigations. Lack of thorough understanding of scientific phenomena leads to predominance in experimental research; consequently we have an abundant supply of men who are willing to conduct experiments, but there are few to generalize or to deduce fundamental laws from experiments. Even practical research does not always meet the proper encouragement. Large industries in times of business depression say they cannot afford it; in prosperity, they do not need it. Professor Karapetoff declared that if we are not to repeat the Russian mistake, we must cultivate the idea of research in the grammar school—even in the high school it is too late. Inasmuch as we cannot do much with the present generation, our activities should not be limited to the universities; we should work for the next generation by starting in the grammar schools to develop a love for Nature and a spirit of inquiry into her secrets.

*Abstract of an address by Professor V. Karapetoff at a meeting of the Engineering Division, National Research Council, February 14, 1922.

ELECTRIC FURNACE VS. OPEN-HEARTH SILICO MANGANESE SPRING STEELS

It is more or less generally recognized that steels of the same composition in so far as the elements used are concerned require variations in heat treatment to produce similar properties. This applies to comparisons between heats made by the same type of process and steels produced by different processes. A series of tests was completed recently by the Bureau of Standards on samples of electric and open-hearth heats of silico manganese spring steels carrying equal proportions of *C*, *Mn*, *P*, *S*, and *Si*. The tests included microscopic examination, tensile test, and determination of proportions of certain gases present, particularly nitrogen and hydrogen. In general, the microstructure of the electric steel was somewhat different from that observed in the open-hearth when both steels were subjected to the same heat treatment.

Under certain thermal treatments, distinct differences in tensile properties were observed, but these were largely obliterated by a preliminary normalizing quench from a high temperature. It was found that the proportion of oxygen present in these steels was practically the same, about 0.028 per cent, and independent of the heat treatment applied. The nitrogen in the original rolled samples of electric steel was approximately twice that of the open-hearth and independent of the heat treatment. However, in the case of the electric steel, the proportions of nitrogen were dependent upon the heat treatment.

The Government Printing Office at Washington has just issued an elementary book on radio communication, entitled "The Principles Underlying Radio Communication."

Numerous circuit diagrams are given, and the construction of antennas and ground connections is described. Besides other useful practical information, the book contains a table of dielectric constants, copper wire tables, wave length tables, the International Code, safety precautions for radio stations, information regarding radio laws and regulations, and a list of radio publications including those issued by the Government.

A copy of this book can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Effect of High Currents on Disconnecting Switches

With Special Reference to the Mechanical Stresses Resulting

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Review of the Subject.—*In the early days of the electrical industry, disconnecting switches adequately performed their functions without the use of locking devices, except perhaps in a few isolated cases, where the blades opened downward, and some mechanism was provided to hold the blade in against the action of gravity (when subjected to jars, vibration, etc.). The generating capacity of central stations at this time was relatively small. Hence, the short-circuit currents obtaining were relatively low, and the forces resulting were insufficient to overcome the friction and other resistance offered by the blade and to cause opening. With the increase in generating capacity came a formidable increase in the short-circuit currents, to such an extent that it was not uncommon for a disconnecting switch to open, causing considerable damage, with consequent demoralization of operation. The result was that there were attempts made to attach locks to switches already installed, and to design new switches of which the lock was an integral part. Many of these locks were found to be inadequate, as opening occurred in many instances. In an attempt to prevent the possible recurrence of such unfortunate incidents the tests described in the following paper were planned; it was hoped thereby to improve the class of service rendered the public and safe-guard the lives of our employees.*

Specifically, it was desired in addition to a general study of the subject, to attempt to improve the locks already in use on our system and to provide locks for the switches located at dangerous points, i. e., points where short-circuit currents are likely to obtain which might open a given switch. One or more of the various types of switches in use on our system were tested, and in addition, a number of types which were considered for replacement of the obsolescent types now in use.

As a result of these tests it was possible by a very simple expedient to raise the opening point of one of our switches from about 40,000 peak amperes to 180,000 peak amperes. A very simple lock was added to another switch largely used on the system which opened at about 51,000 peak amperes so that it would withstand the mechanical forces exerted by 143,000 peak amperes.

The tests clearly demonstrated that some effective form of lock should be provided. This seems to have been generally recognized, and most manufacturers have attempted to take care of this in some way or other. Switches have been constructed (without locks) in which the current through the switch parts does not tend to open the blade. Such switches are satisfactory when used under almost ideal conditions, but certain unfavorable arrangements of the bus and leads usually found in practise, exert magnetic forces which might open the blade under short-circuit conditions, thus completely nullifying the principle of design. Although locking devices are provided they are not always effective, the various reasons being mechanical weakness of lock, current flow through lock, etc. It was noted from a study of the oscillograms that a switch seldom required more than one cycle to open, one-half cycle usually being required.

It was generally recognized that there were outward forces on the blade of a switch due to the passage of high currents; but it was not generally recognized that there were also outward forces on the jaws and insulators tending to spread them apart. These forces must be recognized and dealt with by substantial design as a number of lock failures may be attributed to this. Insulators may fail due to these outward forces, and this can be remedied only by strengthening or properly supporting the insulators.

CONTENTS

THE forces exerted by the abnormally high currents which obtain under short-circuit conditions on large power systems are often sufficient to cause disconnecting switches to open, rupture current transformers, severely injure oil switches, etc.; and the resulting damage to station apparatus is often very great, and human life is ofttimes endangered; furthermore, short circuits which should cause only voltage disturbance, or at worst, partial loss of load, may result in the total loss of load for an extended period. The following report will cover a number of tests made on disconnecting switches with the object of studying the effects of high currents on this class of apparatus. The principal points observed were:

1. The lowest value of current at which a switch blows open.

2. Time required for the switch to open; that is, duration of the short circuit.

3. Cause of the failure of lock, if such is provided on switch, and remedy for the same.

As a result of the mutual interest in such tests, the Pennsylvania Water and Power Company, and the Consolidated Gas Electric Light and Power Company, both of Baltimore, agreed to perform this work together, thus considerably diminishing the cost of an individual test by either company. Each company furnished at least one of each of its various disconnecting switches, and several manufacturers submitted their switches for test, together with several special switches. Many of the better-known makes of switches were tested, and in addition a number of more or less obsolete types.

Method of Tests

Difficulty would ordinarily be encountered in obtaining currents up to 100,000 or 150,000 peak amperes necessary for the testing of these disconnecting switches. Fortunately, the Baltimore Electro Alloys Company was able to spare one of its electric furnace transformers, which normally operates at about 40,000 effective secondary amperes. Three of these transformers

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To be presented at the Spring Convention of the A. I. E. E. Chicago, Ill., April 19-21, 1922.

operate in a bank on one furnace, and all three were actually available if necessary; however, one transformer was found to be ample for our tests.

These transformers are wound for 13,200 volts on the primary, the voltages on the secondary varying from about 138 to 169 (the secondary voltage is varied by changing taps on the primary). The 158- and

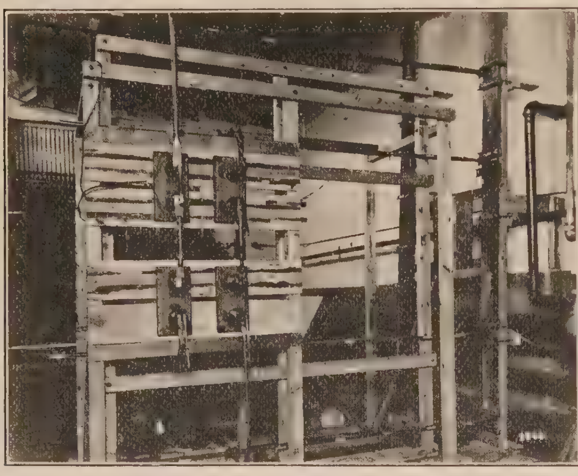

Fig. 1—Bus Structure

169-volt taps were used on these tests generally. To carry the heavy currents, and to minimize the secondary resistance, standard 8-in. by ⅜-in. cold-rolled copper bus was used. Taps were taken from the secondary of the transformer and run horizontally, as shown in Fig. 1, and then vertically downward. Taps were then taken off of the two vertical busses to the reproduced test bus described below.

In order to simulate existing conditions, a bus structure similar in dimensions to those in actual use in our stations was erected as shown in Fig. 1. The top and bottom phases only of the main and auxiliary bus were erected, as these represent the two extreme conditions. The switches were placed as shown, and tested in this position.

In some of the higher-current tests a loop was used (described later) which required the two bus leads from the transformer being run side by side separated by a ⅜-in. asbestos spacer. These two busses with their spacer were held together by heavy clamps spaced from 12 inches to 17 inches apart along the length of the parallel busses. On one of the tests in which the switch opened in one-half cycle at 141,000 peak amperes, the ⅜-in. by 8-in. copper bus actually buckled out away from the asbestos spacer about ¾ in. in the 17-in. braced section. The calculated maximum force between the axes of the busses in the 17-in. section was about 21,200 lb., applied in .01 second (¼ cycle).

The power for the short circuits was supplied by a generator at our Westport steam station of either 7500 kw. or 20,000 kw. capacity as desired, and was connected to the electric furnace transformer by means of a No. 0000, 13,000-volt, three-phase cable, involving a run of about 30,000 ft.

On some of the tests the power source was the Holtwood generating station about 40 miles away. While one machine was used at Westport, it was necessary to use two 10,000-kw. machines at Holtwood to furnish the higher short-circuit currents; the transformers at each end connected by one transmission line completed the arrangement. The fields of the two machines were arranged to be opened simultaneously.

A third arrangement was used for very low currents on several occasions. A frequency changer running inverted was tied in from one of the city substations, by means of some of the city cables, and this machine was used to supply current.

Telephonic communication was provided between the test floor, the Highlandtown substation and Holtwood (or Westport), and this communication was maintained throughout the test.

In the first few tests the short circuits were made by closing in all switches and then closing the field breaker of the generator, and ammeters were used for measuring the current. It was first thought that this scheme might be used in making the tests, thus obviating the use of the oscillograph, and considerably simplifying the tests. However, it was found that the switches heated very rapidly, and would weld together before the current had risen to a value that would have opened them. The large majority of the tests were suddenly applied by closing the high-tension oil switch (Fig. 2), and the oscillograph was used to record the current through the disconnecting switch under test. A second element of the oscillograph was used to record the potential across the switch, and thereby indicate the exact instant of opening.

Oscillograph Application

As stated above the oscillograph was used to obtain a record of the current and voltage across the switch

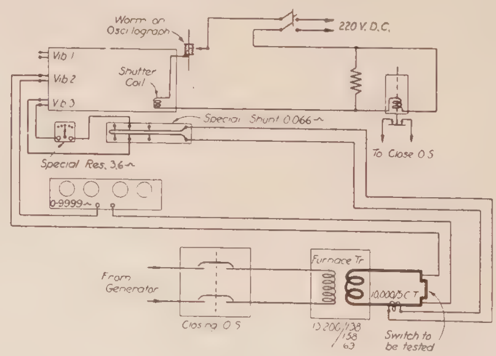

Fig. 2—Oscillograph Set up for Disconnecting Switch Tests

under test. The oscillograph used was the General Electric instrument.

In order to measure currents of the magnitude of 100,000 to 150,000 peak amperes a 10,000/5 Westinghouse through type current transformer was used. On some of the later tests a shunt was used which is

believed to be more accurate than the current transformer in recording transients. Recent tests have shown that current transformers are subject to error in recording transients, the actual current being greater than that indicated by them.

Fig. 2 shows the scheme of connections for the oscillograph. It was desired to have the apparatus so arranged that the operation of the trigger on the oscillograph performed all the necessary functions after the circuit had been set up for test. The sequence of events should be as follows:

1. Shutter of oscillograph opens exactly at beginning of film.
2. Oil switch closes, applying the short circuit several cycles later.
3. After about one revolution of film, short circuit is cleared.

The third item was not automatic on all of these tests, for it was felt that the repeated clearing of a number of heavy short circuits by an oil switch was undesirable, and so it was decided to clear the short circuit by opening the field of the generator. This was done at the generating station by the operator as soon as he observed that the short circuit was on.

The method of obtaining the required sequence is shown in Fig. 2. Instead of operating the oscillograph shutter from a six-volt battery, 220 volts d-c. was used and an auxiliary relay placed in series with it (the shutter). This relay had its contacts connected to the "close" leads of No. 3 feeder oil switch.[1] When the trigger of the oscillograph was pulled, the moving contact dropped down into the thread of the hard rubber worm and, at the instant the film overlap was opposite the slot, made contact with the metallic thread. This opened the shutter and closed the auxiliary relay which closed the oil switch, throwing on the short circuit. This arrangement caused the initial rush of current to take place near the beginning of the film. The operator at the generating station would then open the field of the machine causing the current to die out.

The oscillograph was at first calibrated before and after each series of tests, but this was found to be unnecessary as there was practically no difference in the two calibrations. Alternating current was used almost exclusively in making the calibrations, principally on account of its convenience.

Procedure in Test

After a switch was in place for test the contacts were given a final examination, as was the alignment of the blade and jaws. The pull in pounds necessary to open the switch was then measured at the eye of the switch by means of a spring balance, and this pull adjusted to what was thought to be a normal value, by bending the jaws if necessary. This necessitated further inspection of the jaws for good contact. After the test was made the pull required to open the switch (in case it did not open) was again measured.

When it was desired to make a test on a switch one of the above mentioned circuits was set up with No. 3 feeder oil switch open. When everything was in readiness the operators were notified that the switch would be closed in one-half minute. The oscillograph was given the final adjustments, and at the expiration of the 30 seconds it was operated. The oil switch was opened manually after the film had made one revolution

1. In primary of electric furnace transformers used on these tests.

SUMMARY OF TESTS

	Make	Rating (Amps.)	Fig. No.	Lock	Test Current Peak Amps.	Equivalent Peak Amps.	Did Switch Open?	Pull in lb.	Half-Cycles to open	Remarks
a	*A*	300	3	No	34,100	34,100	Yes	17	1	
b	"	300	7	Yes	40,500	40,500	Yes	17	1	
c	"	300	8	Yes	84,100	84,100	Yes	16	1	With make *D* lock & ins'l.
d	"	600	..	No	75,000	75,000	Yes	28	2	
d′	"	600	..	Yes	56,700	56,700	Yes	12	1	Note pull is less than *d*
e	"	300	11	Yes	125,000	170,000	Yes	16	13	Notched blade
e′	"	300	..	Yes	133,900	178,000	Yes	20	1	Pinned blade
f	"	300	13	Yes	105,300	127,000	Yes	22	1	Latest type
g	*B*	300	15	Yes	66,800	66,800	Yes	13	1	Type *O*
h	"	300	16	Yes	53,900	53,900	Yes	13	1	Selector type *O*
i	"	300	17	No	39,000	39,000	Yes	20	3	Type *M*
j	"	300	..	No	51,200	51,200	Yes	20	1	Plain Ins'l.
j′	"	300	18	Yes	116,000	143,000	No	20	..	Plain Ins'l.
k	"	600	19	Yes	84,500	84,500	No	35	..	Type *P*. Not completely tested
l	"	300	20	Yes	34,000	34,000	Yes	12	13	Type *P* 35 Kv.
m	"	1200	21	Yes	142,000	208,000	No	40	..	
m′	"	600	..	..	90,700	90,700	..	20	..	Did not open under cond. for which designed
m″	"	1200	22	..	93,000	93,000	No	24	..	
n	*C*	600	..	No	52,200	52,200	Yes	19	5	Lock taken off
n′	"	600	23	Yes	144,000	181,000	No	22	..	
o	"	300	25	Yes	129,000	152,000	No	19	..	
p	*D*	300	..	No	28,200	28,200	Yes	18	1	Selector type
p′	"	300	26	Yes	41,600	41,600	Yes	9	29	
q	"	300	29	Yes	90,900	113,000	Yes	17	6	Insulators broke
r	*E*	300	30	Yes	141,000	169,000	Yes	22	1	
s	*F*	300	31	Yes	74,500	120,000	Yes	27	3	
t	Leilich	600	32	Yes	68,000	68,000	No	12	..	Test not complete
t′	Special	800	33	Yes	81,500	81,500	Yes	90	..	
u	*G*	300	34	Yes	124,100	151,000	Yes	22	9	
v	"	600	..	Yes	145,000	193,000	No	50	..	

as by this time the operator had opened the field breaker and the current had died down to a low value. At least one other oil switch was then opened together with the disconnecting switches at the primary of the furnace transformer before anyone was permitted to examine the switch tested. The film was developed and the magnitude of the current ascertained.

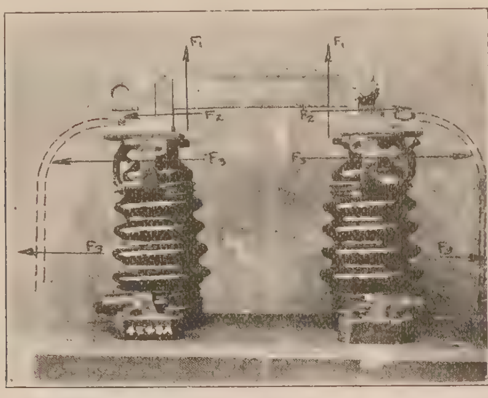

Fig. 3

In case the switch did not open another test was usually made at a higher current, but not before carefully dressing and polishing the burned parts.

Results of Tests

The accompanying tabulated summary of tests shows both the *test* current and the *equivalent* current. This item "equivalent current" is intended to take care of the added force produced by the rear bus when a switch was tested in the loop (to which reference was previously made). It is the current which would produce the same force met with in test if there should be no rear bus present. If the switch was not tested in the loop, the test current and the equivalent current were the same. The basis of this calculation is

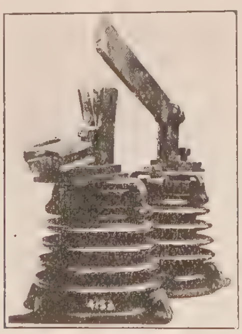

Fig. 4

the formula proposed by Mr. H. B. Dwight in the June 1920 Journal of the A. I. E. E. As calculated, the effect of the side busses is ignored, and the rear bus only is considered.

This tabulation may be used to compare the various switches tested; and in addition a brief discussion of some of the more interesting points of the tests will be given.

It has been previously recognized that there are outward forces on the blade of a disconnecting switch, when subjected to high currents, that tend to open the blade. These forces are shown as $F_1 F_1$, Fig. 3. However, in addition to these forces there are other forces tending to separate the jaws and insulators, as shown at $F_2 F_2$. When the connections are run to the switch as shown by the dotted lines, there is repulsion between these conductors as shown in $F_3 F_3$. In a description of some of the tests in the appendix, it will be shown that many designers of locks have completely ignored the forces $F_2 F_2$ and $F_3 F_3$. These horizontal forces tend to open some types of locks, and to break off the insulators. For this reason locks should be either on the outside of the loop, or some means should be taken to prevent the insulators from spreading.

It was observed on many tests in which the blade opened, that the break jaws spread apart (see Fig. 4). As the two sections of this jaw carry current in the same direction, one would expect them to be drawn together, which occurred only in one or two cases. The only explanation that has been advanced is that the explosive action of the metal vapor or of a small quantity of oil that might be present, forces these sections apart.

In the 43 cases in which the blades of the switches were blown open, 21 cases were within the first half-cycle, 9 cases required one cycle, and 14 cases required more than one cycle for opening. The conclusion might be drawn that a switch will ordinarily open within the first cycle, and possibly within the first half cycle. It is evident from this that it is not the average force exerted by the current which opens the switch, but the maximum force resulting from the peak value of current, and it is this peak-value which should be used in all short-circuit calculations pertaining to the forces acting on disconnecting switches. Furthermore, it is the *initial* peak which will more than likely cause opening. And it should be remembered that this initial peak may have a displacement of twice the symmetrical value usually used in short-circuit calculations.

It was found that the major portion of the locks tested were incorrectly designed. In fact, one manufacturer asserted that electrical expulsion forces only tend to hold this lock more firmly in its place. And as a matter of fact examination of the switch and lock would lead one to believe that such was the case. Yet this particular lock proved to be rather inferior, and blew open at relatively low currents. (Make *F*).

One of the causes of the failure of a number of effective looking locks is due to the fact that designers have failed to take into consideration the fact that in addition to the outward forces on the *blade*, there are outward forces on *each insulator*, which are ofttimes just as effective in causing the lock to open as the outward forces are in causing the blade to open. (Makes *F, D, B* type *P*).

Another cause of at least two types of locks failing is the fact that the lock itself carries current, and repulsion by other current carrying portions cause the lock to open. (Make *B* Type *C*, *D* Selector type).

Still another cause is due to inherent mechanical ineffectiveness of the lock. By this is meant that the lock simply does not hold even when a simple mechanical pull is exerted on it. In this class would come the two types of Make *D*, and Make *B* type *P* locks.

And there is the switch that has a lock that is not mechanically strong enough to resist the forces. This includes the Make *B* lock on the type *O* selector switch, the Make *A* lock, and the Make *E* lock.

The fact that a lock may carry some of the current may cause it to fail thermally. The failure of the Make *A* lock might be attributed to this cause, as might be the failure of the Make *B* type *O* selector switch lock. As a matter of fact it may have been a combination of mechanical and thermal effect which caused these locks to fail.

Fig. 5

It is desired to call attention to the fact that there is a tendency toward building a switch with the current-carrying portion too light, which is typified in a number of the switches which failed to stand up under test.

Generally speaking, it is believed that the double blade disconnecting switch (such as Make *C*) is superior to the single blade switch, particularly where the design is such that it permits the blades to clamp the jaws due to the parallel high currents flowing in the same direction. Furthermore there is more radiating surface per unit cross section of the blade on this type of switch. It also permits the switch to be so constructed that the contact pressure is readily adjustable.

It may be stated here that while bringing the return circuit behind the switch materially adds to the force action on the blade and hence renders it more liable to open, this is preferable to running it *alongside* of the blade which is still more likely to open the switch. With the return conductor alongside of the blade, a side blow is delivered for which the switch was not designed. This is shown in Fig. 5 where the return conductor was run alongside the blade, and the switch was badly injured.

It is merely repetition to state in this report that switches should not be placed in loops if it is possible to avoid them; but this is usually determined by the original design of the station, and concerns generally station designers rather than operating engineers.

These tests show that the Make *C* switches are generally speaking superior to the other switches tested. This applies to mechanical construction and performance on the tests. Several years ago some difficulty was experienced in these insulators failing on high potential test, but data at hand shows that this defect has been largely remedied.

It might be mentioned here that the split hinge jaw is thought to be undesirable, as it may open instead of the lock. This is described fully in the appendix.

Appendix

This appendix is intended to give briefly detailed information concerning all of the important switches tested. Many switches are included here which may be more or less obsolescent; these switches are included for one of two reasons; first, some point is brought out that is thought to be of general interest; second, these switches are in more or less general use, and the information may be of value to the users.

It is desired to call attention to the fact that these tests were not made primarily to compare the most recent designs of disconnecting switches of the various makes, but to obtain data on switches in actual use on our system.

Over two hundred tests were made, covering in all about thirty types of switches. The manufacturer will in each case be designated by a letter as *A*, *B*, *C*, *D*, *E*, *F* and *G*. It will be noted that peak values of current only are used.

(*a*) *Make A 300-Ampere Switch Without Lock, Fig. 3.* A single blade is provided with a hinge jaw split in three parts, and the break jaw in two parts. The insulators are mounted on the base by means of a clamp and *U*-bolts, and the two jaws are mounted by a similar arrangement. It is believed that this scheme is rather inferior as it permits considerable motion of the insulator.

About 28 tests were made on this switch. The first scheme was to start at a low generator voltage, say 4000, and gradually work upward in steps of 500 or 1000 volts, making three tests at each voltage. But this method was soon found to be unreliable as after a few tests the blade and break jaw would become burned and pitted so that welding would take place, and the switch would not open at all. The method then adopted was to examine the switch to be tested, and

estimate the current that it would withstand and test at that current value; then, after an examination of the switch after test, a next higher (or lower) current would be decided upon, and so on until the switch

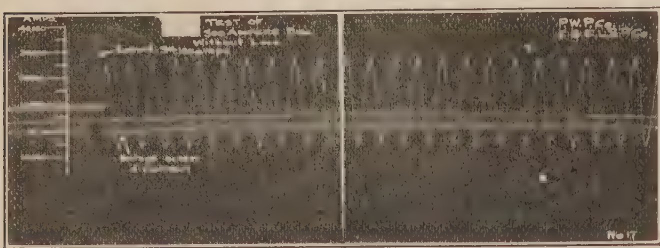

Fig. 6

opened. The pull at the eye of the switch was adjusted before each test to be about 15 to 17 pounds, corresponding to 16.5 to 18.5 pounds at the break jaw.

This switch opened on the first three tests at 43,100, 36,000 and 34,100 peak amperes in ½, 1 and ½ cycles respectively. The latter figure, 34,100, is the lowest value at which the switch opened.

Fig. 6 (Oscillogram 17) shows the switch opening in one-half cycle at 34,100 peak amperes. The mechanical force at the break jaw required to open the switch on tests No. 17 was 18.5 pounds. The current required to exert this force is 38,400 amperes, calculated from the Dwight formula. The switch actually opened at a current 11.2 per cent lower than this (34,100 amperes).

It would be expected that the actual current required would be greater than 38,400 amperes, as the attraction of the two sections of the switch jaws (at the break jaw in particular) should exert a pressure on the blade, thus increasing the pull at the break jaw above 18.5 pounds. The two sections of each of the jaws carry current in the same direction, and hence attract each other.

It was noted that in most cases when the switch blew open the break jaws spread apart. That is best shown in Fig. 4, another type of switch being shown.

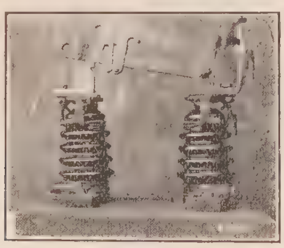

Fig. 7

This may be due to the explosive action of the metal vapor as the switch opens, or to the presence of a small quantity of oil in the jaw, or to both.

On several subsequent tests the switch failed to open at somewhat higher currents, but this was found to be due to welding. This is shown rather conclusively in tests No. 39 and No. 40, where the burned break jaw of previous tests was replaced by a new one. The switch opened in these two tests at 39,200 peak amperes and 35,900 peak amperes, while on a number of previous tests currents up to 46,500 peak amperes failed to open the switch with the burned jaw in place.

Fig. 8

(*b*) *Make A 300-Ampere Switch with Make E Lock Attached.*

This switch is identical with the previous switch except that a lock has been added as shown in Fig. 7. The lock is of more or less familiar design, and will not be described further than to say that the latch fits into a notch filed into the jaw of the switch.

Both the hinge and break jaws of the switch are slotted as shown in Fig. 7; and while this probably gives better contact, the switch is materially weakened, especially at the hinge jaw. For when a hole is drilled through the middle section to receive the hinge bolt there is little metal left to resist the outward forces. As a matter of fact, on one of our tests on this switch (described later) the switch blew open at the *hinge* jaw rather than the break jaw due to this weakened condition.

Five tests were made on this switch, which opened at 40,500 peak amperes. From an examination of the lock it would appear that such an arrangement would hold against the action of almost any reasonable current, or at least up to the point where the dogs of the latch would shear off. But it should be remembered that in addition to the outward component of force tending to open the *blade* there is an outward

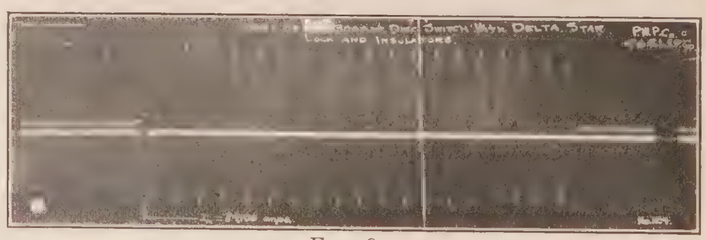

Fig. 9

component tending to spread the *break* and *hinge* jaws and pull the latch out of engagement with the notch. This was confirmed by a number of tests in which markings were made on the blade of the switch before test and noting the position after test. Movements of 3/16 in. were frequently noted. Welding of the blade and jaw often took place, and a blow would bring the blade and jaw back into normal contact.

(c) *Make A 300-Ampere Switch with Make D Lock and Insulators.*

The weakness in the above switch with lock was found to be in the insulators, and it was believed that if more rigid insulators were used the lock would be more effective. Hence the arrangement shown in Fig. 8 was made up similar to the above mentioned switch except that more rigid insulators were used. This

Fig. 10

arrangement opened at 84,100 peak amperes, or more than double the value with the original insulators (40,500). Fig. 9 (Oscillogram 124) shows the switch opening in one-half cycle. Fig. 10 shows the burning at the break jaw and blade. The jaws in this particular case actually drew together and welded, which is exactly opposite to the action that usually exists, as shown by Fig. 4.

(d) *Make A 600-Ampere Switch.*

This switch is similar in construction to the 300-ampere switch, with the exception of the current-carrying parts which are correspondingly heavier.

Tests were made with and without lock, as in the 300-ampere switch. Without lock, the opening occurred at 75,000 peak amperes, with a pull at the break jaw of 28 pounds. In testing with lock, the break jaw pull was reduced to 11.5 pounds to make the lock itself withstand the force action, as far as possible. Under these conditions the switch opened at 56,700 peak amperes.

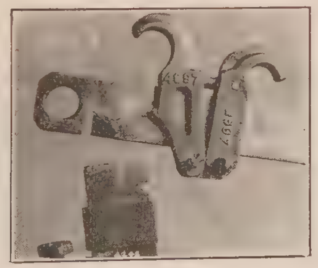

Fig. 11

(e) *Make A 300-Ampere Switch with Special Locks.*

In an effort to find a simple and effective lock for this switch, a number of designs were constructed, such as pin lock (the pin passing through both blade and jaw), door latch arrangement (on the outside of break jaws), notched blade lock, pinned blade lock, etc.

Fig. 11 shows a satisfactory arrangement in which the blade of the switch notched so as to fit down over the clamp around the jaws. The object in this arrangement is obviously to prevent the insulators and jaws from spreading with the consequent disengagement of the latch. This scheme was very effective, the current required for opening being 125,000 peak amperes. Opening occurred after 13 cycles, the current having died down to 102,000 peak amperes. The dogs of the latch sheared off as shown in Fig. 11, thus permitting opening. This is one of the few cases in which more than one cycle was required to open a switch. Figure 12 shows the phenomena.

A somewhat similar scheme, designated as the pinned blade lock, held up equally well on subsequent tests. Instead of the blade being notched with a clamp around the break jaws, a pin was driven through the blade

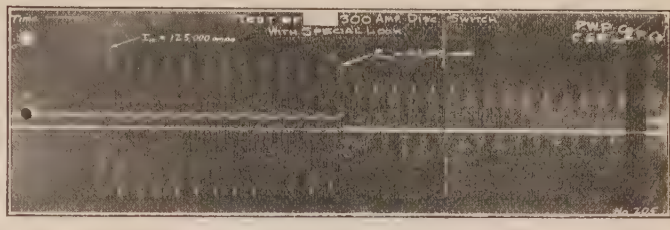

Fig. 12

which butts against the break jaw thus preventing any outward motion.

(f) *Make A 300-Ampere Switch with Make A Lock.*

It is understood that at the time of test this switch was the latest design by this manufacturer. The current-carrying portions are very similar to those of the older type; but the insulators show considerable improvement. Fig. 13 shows this switch with the new

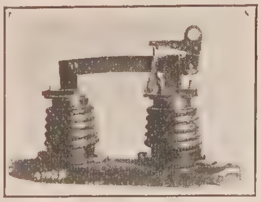

Fig. 13

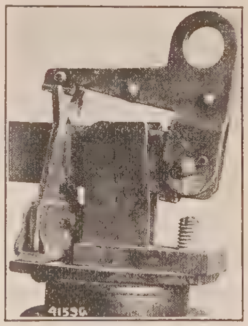

Fig. 14

type of lock in place. Fig. 14 shows a more detailed view of this lock from which its operation is evident. It is believed that the lock occupies considerable space for its effectiveness. Furthermore, the quality of workmanship is not as high as in the other portions of the switch. The insulators are strong and well constructed, and showed no signs of weakness in the tests. The method of mounting the insulators could be improved, as it is necessary to remove the entire switch to make replacements. It is worthy of note

that the effectiveness of this lock is not dependent upon the rigidity of the insulators.

The switch was given five tests up to 90,300 peak amperes, which current was effectively withstood. However, burning was evident on all tests, and on the fifth test the blade turned red. A sixth test was made at 105,300 peak amperes, and the switch opened after one-half cycle, burning the blade, jaws, and lock badly as shown in Figs. 13 and 14, these pictures being taken after the last test. It is thought that the tips of the dogs sheared off, permitting the blade to open. The arc then burned the lock, blade and jaws as shown.

The dogs butt directly against one another, and the amount of metal that resists the shear of the blade is small. The lock could be so designed that the two dogs would be staggered and each one would then extend all the way over the blade, thus offering considerably more metal to resist shear.

Test was made with the switch in the loop previously referred to. The calculated force due to this rear bus was 112 pounds at the break jaws, and the force due to the current passing through the switch was 227 pounds, giving a total force of 339 pounds at the break jaw. This force is equivalent to a current of 127,000 peak amperes through the switch, if there were no rear bus present, ignoring the effect of the sides of the loop. The pull at the break jaw was 21.5 pounds for this test.

Fig. 15

(*g*) *Make B 300-Ampere Type O Switch with Lock.*

Fig. 15 shows the construction of this rigid insulator switch. The blade is double but is so constructed that it does not properly take advantage of the clamping action of the blades. This clamping action due to the passage of current in the same direction in the two sections, might be utilized in clamping the break jaw, both increasing the friction and insuring better contact. This force action is felt only during the flow of high currents through the blade. The lock is a simple hook arrangement located on the outside of the loop formed by the conducting portion of the switch.

The lowest current at which this switch opened was 66,800 peak amperes in one-half cycle, breaking off the hinge jaw insulator. Burning at the lock indicated that it carried current, and it was thought that forces might have resulted which caused the lock to open. To confirm this suspicion, currents averaging about 60,000 peak amperes, sustained value, were passed through the switch with the blade bolted shut and a contact mechanism in front of the lock (about 3/16 in. distant). This contact mechanism completed a battery circuit through the oscillograph vibrator, and at the above current repeated contact was made as shown on the oscillograph film, indicating that this was the cause of the lock opening.

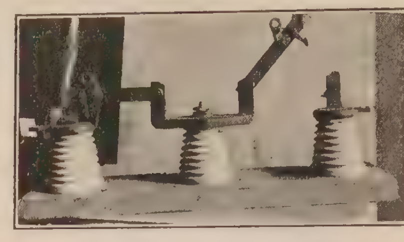

Fig. 16

(*h*) *Make B 300-Ampere Selector Type O Switch with Lock.*

Fig. 16 shows this switch with its locking mechanism. It is rated at 300 amperes, but the current-carrying parts are fragile as compared to other switches of the same rating. Opening occurred at 53,900 peak amperes. The lock was bent and badly burned. A part of the break jaws welded to the blade, and was pulled off with it when opening occurred (see open blade in Fig. 16).

Fig. 17

Fig. 18

(*i*) *Make B 300-Ampere Type M Switch without Lock.*

The type *M* switch (Fig. 17) is one of the older designs, and was tested for the reason that a number of them are in use at this time. With a break jaw pull of 20 pounds, opening occurred at 39,000 peak amperes.

(j) *Make B 300-Ampere Plain Insulator Switch.*

The name "plain insulator" switch was applied to this type for want of a better name. In fact, there is no marking on the switch to indicate the maker, but the assumption that it was a Make *B* switch was confirmed by one of the maker's representatives. Fig. 18 shows the switch, provided with a lock, described below. While the design of this switch is not beyond criticism, it must be said that the workmanship is as good as on any switch tested, referring principally to the current carrying parts. The current required for opening was 51,200 peak amperes (without lock), with a break jaw pull of 20 pounds.

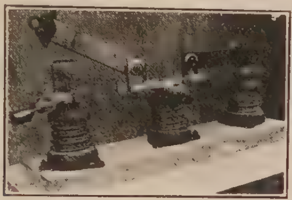

Fig. 19

As many of these switches were in use on the system located at points where short-circuit currents of sufficient magnitude might obtain to cause opening, it was desired to apply some sort of locking mechanism to this switch that would render it safe up to approximately 100,000 peak amperes. The scheme finally decided upon is shown in the illustration. It has the disadvantage that two motions are required to close and

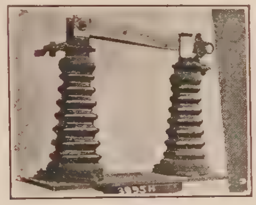

Fig. 20

lock the switch, one to close the blade, and one to lock the switch. The first test was made with the lock pedestal insulated, and the blade held satisfactorily at 116,000 peak amperes. The insulation was then removed permitting the lock to carry a portion of the current. It was then tested at 96,600 peak amperes, which was successfully withstood.

Testing was with a rear bus present and 116,000 peak amperes is equivalent mechanically to 143,000 peak amperes passing through the switch with no rear bus.

(k) *Make B 600-Ampere Selector Type P Switch with Lock.*

This switch, Fig. 19, was never completely tested, as it was received in such condition as to require considerable dressing before it could be put in service. The type of lock used will be discussed later. It might be mentioned that several tests were made on this switch as received and it did not open (up to 84,500 peak amperes) due to the burning and welding at the contacts.

(l) *Make B 300-Ampere (35,000-Volt) Type P Switch with Lock.*

Fig. 20 shows this switch. The lock is similar to the switch previously mentioned. It is not particu-

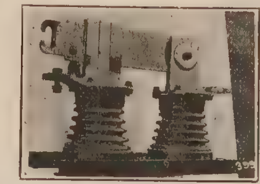

Fig. 21

larly effective, for it may be opened with a little effort by pulling on the blade. Opening occurred at 34,000 peak amperes, after 6.5 cycles.

(m) *Make B Switches of other Types.*

Fig. 21 shows a 1200-ampere type *S* switch, one of the later switches of this make. The locking mechanism is fairly simple and substantial. With a pull at the break jaw of 39.5 pounds, 142,000 peak amperes

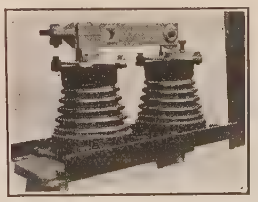

Fig. 22

failed to open it. This is equivalent mechanically to 208,000 peak amperes as the test was with a rear bus.

Fig. 22 shows a 600-ampere switch designed by Mr. F. E. Ricketts, of Baltimore. The principle, that of avoiding loops is obvious. The jaws are so designed that the current passes straight through the switch, thus eliminating any tendency to open. The first

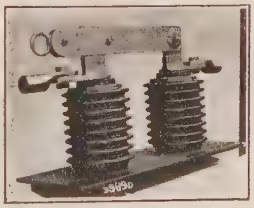

Fig. 23

Fig. 24

group of tests was made with the connections extending in a straight line on either side of the switch for about five feet, thus avoiding loops that would tend to open the blade. With these connections the switch remained closed up to 90,700 peak amperes. The connections were next brought in from the rear at right angles to the blade, in the plane of the blade opening, thus form-

ing a short loop (about 17.5 in. between the two leads). Opening occurred after 18.5 cycles at 58,300 peak amperes. As the connections to a switch in service are usually as in this last test, it is felt that this scheme is

Fig. 25

Fig. 26

hardly applicable to most installations. The design may prove valuable in bus section switches, or other places where loops are avoided.

A 1200-ampere switch of this design was tested up to 93,000 peak amperes, but it showed no signs of distress. No attempt was made to test it further.

Fig. 27

(n) Make C 600-Ampere Switch with Lock.

Relative to the design and construction of this switch it might be said that it is the equal of any switch tested. Fig. 23 shows the switch to be a double blade switch with jaws and lugs cast integral. The blade is so designed as to take full advantage of the clamping

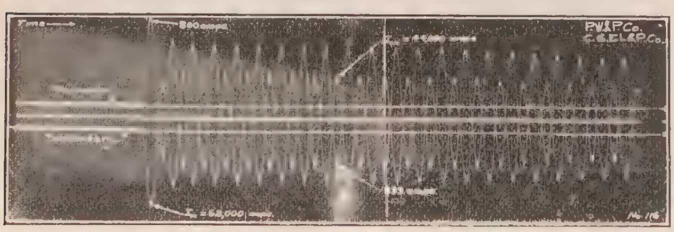

Fig. 28

action due to the passage of high currents. The lock is simple and strong. The contact between the blade and jaw is ground giving accurate contact, and these jaws may readily be removed without changing the insulator. Fig. 24 shows the lock mechanism, which is located on the outside of the break jaws. Outward movements of the insulator will not tend to disengage it.

It was impossible to open this switch at currents up to 144,000 peak amperes, which test was with rear bus, and equivalent mechanically to 181,000 amperes. The burning was relatively slight up to 111,000 peak

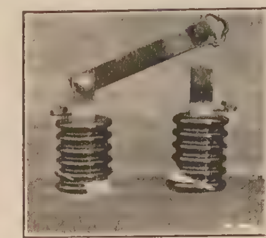

Fig. 29

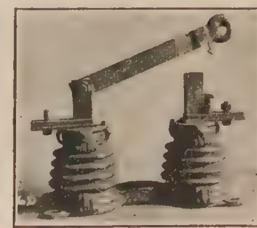

Fig. 30

amperes. Fig. 24 was taken after the tests were completed and shows the relatively slight burning even at these high currents. This switch with its locking mechanism remained operative after the tests were completed.

Without locking mechanism this switch opens at 52,200 peak amperes.

(o) Make C 300-Ampere Switch with Lock.

The 300-ampere switch is similar in design to the 600-ampere switch described previously. Currents up to 129,000 peak amperes failed to open the blade, the mechanical equivalent due to the rear bus being 152,000 peak amperes. On previous tests the blades were drawn together somewhat and the hinge jaw lug was bent due to the burning loose of one of the leads. This lug was straightened out, and on this last test burned loose at the end of the eighth cycle. This is obviously the fault of the bend in the lug, and not an inherent fault in the switch. Fig. 25 shows this burn, and in addition, the drawing together of the blades due to the passage of high currents.

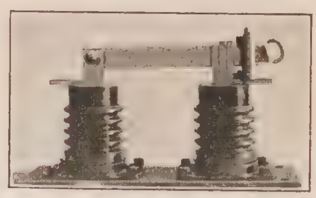

Fig. 31

(p) Make D 300-Ampere Selector Type Switch with Lock.

This familiar type of switch is shown in Fig. 26, in which the mounting of the insulators with the studs running through to form the back connections, may readily be seen. Attention is called to the large loop formed by these studs which means that a relatively great outward force is exerted on the blade, for a given current through the switch. However, the outward forces on the break and hinge jaws cause no movement due to the method of supporting the insulators. The lock used on this switch consists in a hinged leaf engaging in a notch in front of the break jaw.

The switch was first tested with the lock removed. With a break jaw pull of 16 pounds the opening occurred at 28,200 peak amperes in one-half cycle. The lock was then replaced and the break jaw pull reduced to about 8 pounds. Opening occurred after 15 cycles at 41,600 peak amperes.

The switch was then tested with both of the break jaws alive at one polarity, and the hinge jaw alive at the opposite polarity. The blade opened at 48,100 peak amperes after one cycle and blew into the opposite jaw, thus establishing the current again, blowing back and forth, making four contacts in all. Fig. 27 (oscillogram 74) shows this phenomena with the duration of contact and the interval between.

Fig. 32

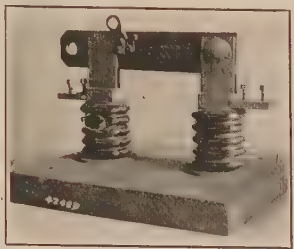

Fig. 33

It could not readily be seen just why this lock should open, and the only explanation advanced was that some of the current flowed through the leaf in such a direction as to cause repulsion between the blade and itself. This seemed very unlikely however, and several lock opening tests were made similar to those described above, by bolting the blade to the jaw. The oscillograms showed that the lock opened at the peak of each half cycle. An examination of Fig. 28 (oscillogram 166) shows this opening, the notches in the middle line under the peak of each half wave indicating that the lock opened and made contact.

(q) Make D 300-Ampere Switch with E N Lock.

In Fig. 29 is shown one of the latest locks of this make. It will be noted that the hinge jaw is not split which is a very desirable feature. At a current of 90,300 peak amperes the insulators broke off, which evidently permitted the lock to open, but with stronger insulators it is believed that the lock might stand up better. The "equivalent" current in this case was 113,000 peak amperes.

(r) Make E 300-Ampere Switch with Lock.

This switch is, generally speaking, more generous in its proportions than many other switches tested. The hinge jaw is not split, making a strong hinge joint. The break jaw is split, but due to the design of the lock, this is not a disadvantage. The locking mechanism is contained in a head riveted on the end of the blade, as shown in Fig. 30.

This switch showed up well up to 75,800 peak amperes but at 141,000 peak amperes (break jaw pull 16 pounds) the blade opened. Examination showed that the head had pulled off of the blade, probably due to the shearing of the three rivets which holds the lock head on the blade. Fig. 4 shows this switch after tests. As this last test was in the loop the 141,000 peak amperes is mechanically equivalent to 169,000 peak amperes.

(s) Make F 300-Ampere Switch with Lock.

There are many features in the design of this switch, Fig. 31, which are worthy of note, such as the solid hinge jaw, the adjustable and interchangeable insulators the locking mechanism, etc. To all outward appearances the lock is well made and effective. For this reason no attempt was made to test at the very low currents. Several tests were made in which the blade opened at currents from 65,000 to 75,000 peak amperes.

A thorough examination of the switch was then made to determine just why the lock should open. It was found that when the insulators were spread apart the lock opened, due to the cams on the pull ring pushing against the dogs which open the lock. The remedy that suggested itself was to separate the cams and dogs 1/8 in. by moving the insulators together by this distance. This being done, the switch was tested at 121,700 peak amperes, at which current both insulators broke off and the lock opened, releasing the blade. The current equivalent mechanically to 121,700 peak amperes (due to the rear bus) is 154,000 peak amperes.

(t) Miscellaneous Makes Tested.

Fig. 32 shows a cam lock fitted on a standard make switch, designed by Mr. F. T. Leilich of Baltimore. This lock consists of a cam which presses against the

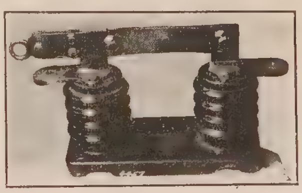

Fig. 34

break jaw when an outward force is exerted on the blade or jaw. The switch was tested up to 68,000 peak amperes without opening, but injury to the switch prevented it being tested further.

Fig. 33 shows an arrangement of parts made by various manufacturers and used at various points on the system. With the lock properly adjusted 81,500 peak amperes opened the blade.

(u) Make G 300-Ampere Switch with Lock.

In Fig. 34 is shown a switch very similar in design to the Make *C* switch. The photograph was taken after the switch had been opened at 124,100 peak amperes, equivalent mechanically to 152,000 peak amperes. Attention is again called to the drawing together of the blades.

(v) Make G 600-Ampere Switch with Lock.

The 600-ampere switch is similar in design to the 300-ampere switch described in the preceding paragraph. Currents up to 145,000 peak amperes, equivalent mechanically to 193,000 peak amperes, failed to open the blade.

ILLUMINATION ITEMS

By The Lighting and Illumination Committee

HIGHWAY LIGHTING

Illumination helps to make highway travel easier at night. It helps to reduce traffic congestion, relieves eye-strain and assists in making repairs after dark. It increases night traffic and thereby relieves day congestion. It increases running time and thereby increases road capacity. Illumination of the road-bed at night would be a big factor in reducing traffic accidents. Data presented before the Illuminating Engineering Society in October by E. A. Anderson and O. F. Haas show that nearly 18 per cent of the night traffic accidents in cities can be attributed to inadequate or improper lighting, and obviously, the percentage of traffic accidents on country roads and highways due to poor lighting is much higher.

An installation which is of particular interest in this connection is the one recently made on the part of the State Road from Schenectady to Albany, N. Y. This installation was made to determine the best method of application of a new design of highway lighting unit recently developed for the lighting of public roads and highways. This unit consists of a nest of reflectors, one within the other. Two of these nests direct the light toward the roadway at an angle of 10 degrees below the horizontal. There is also some light directed below the unit, owing to the opening just below the tip of the lamp. The bracket holding the reflector is adjustable in both vertical and horizontal directions so that the fixtures can be mounted on poles close to the edge of the highway or at locations which may be some distance away from the roadway.

Nine thousand feet of this road was lighted, all of which was of concrete except 800 feet of yellow brick. Twenty four units were used. Spacing distances of 300 and 400 feet were first tried, with 250-candle power series incandescent lamps. Spacings of 500 and 600 feet with 400-candle power series incandescent lamps were then tried. It was found that the 400-candle power lamp was too brilliant for this service at the heights used here, and that satisfactory lighting is obtained from 250 candle power lamps spaced 250 to 400 feet apart, depending on the road surface and traffic conditions. Thirty to thirty-five feet was found to be the most satisfactory mounting height; the units in this installation were mounted 30 feet high. It was estimated that such a system could be installed and operated at an annual rate of $50.00 to $70.00 per unit, which would include interest and depreciation on the initial investment.

TEXTILE MILL LIGHTING STANDARDS SEVEN YEARS AGO AND NOW

In an authoritative text-book on Industrial Lighting, which was published in October 1913, a textile mill installation was described as follows: "In the weave room, one 60-watt lamp equipped with a bowl-shaped aluminized reflector giving an intensive distribution of light is installed for each four looms. The lamps are placed 10 feet above the floor. For spinning rooms, the standard practise is to place three lamps between each alternate pair of frames suspended at a height of to feet 6 inches. The units are similar to those employed in the weave room. The mill described manufactures white goods exclusively. The illumination is considered satisfactory". (Such a system supplied from 1 to 1½ foot-candles of illumination on the work.)

During the recent war, when every possible means was used to stimulate industry and to increase production, the advantages of higher levels of illumination became more evident. The standards for all classes of work were gradually raised, and installations giving 10 foot-candles became common; in certain locations as high as 15 and 25 foot-candles were used to advantage.

Up until about the time the war ended, lighting standards in textile mills were essentially the same as those which existed back in 1913 and 1914. At this time, however, the efforts of lighting men were concentrated upon these textile plants, with the result that the lighting standards in the textile industry today are considerably higher. Where the 60-watt clear lamp used to be considered satisfactory for each group of four looms in a weave room where light-colored goods were being made, the 200-watt bowl-enameled lamp in a dome reflector is now employed. This latter combination supplies in the neighborhood of 6½ foot-candles after being in service some time, and about 8 foot-candles at the time of installation. In locations where the material handled is of a dark color, as, for instance in mills making blue denim overalls, illuminations of 12 and 14 foot-candles are now commonly employed.

These figures show clearly the change which has been effected to date in textile mill lighting. Generally speaking, the illumination *in use* today is more than three times that *recommended* as satisfactory in 1913. It is probable, too, that the next few years will bring even higher illumination standards in this industry as the advantages of the present standards become more evident.

LEADING FIXTURE MANUFACTURERS STANDARDIZE ON ELEXIT DEVICES

The need for adopting a single form of device which would make it possible to "hang a fixture like a picture" was early realized by a number of manufacturers of lighting fixtures and similar equipment, who met together to work out the details of standardizing on a single device which would best meet the requirements for making lighting fixtures portable. The opinions of such groups as the National Association of Electrical Contractors and Dealers and the National Council of Lighting Fixture Manufacturers were consulted

that all of the conditions that must be met might be thoroughly understood. Likewise, individual fixture manufacturers, electrical contractors, and the representatives of other groups whose interests were to be affected by this devise were consulted. After a period of deliberation lasting about six months, during which

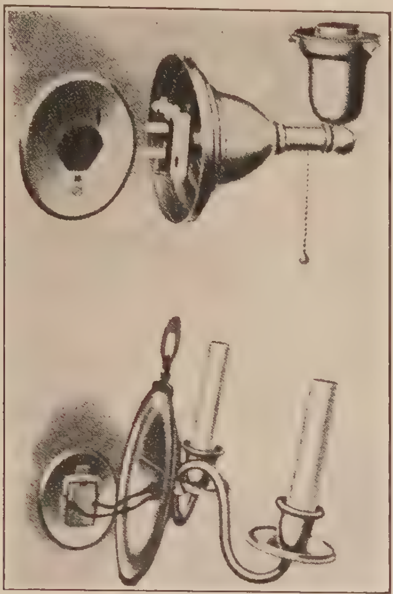

Fig. 1—Views Showing Rigid and Flexible Types of Wall Bracket Connections

time a great number of removable fixture devices were developed and analyzed, the manufacturers entered into an inter-licensing plan under which they will manufacture and sell one particular device which they have standardized in every respect necessary for interchangeable use.

Views of the several types of receptacles and plugs standardized are shown in Figs. 1, 2 and 3. It will be noted that they correspond very closely to the removable lighting fixture devices known as elexits which were

Fig. 2—Types of Standard Plates for Attachment of Wall Brackets

placed on the market somewhat over a year ago. From now on the word elexits will be used in the electrical industry in an altogether general sense to designate the newly-standardized device.

In manufacturing the new elexits absolute standardization is provided for, and all elexit parts are interchangeable between receptacles and plugs regardless of the origin of their manufacture. Thus can a fix-

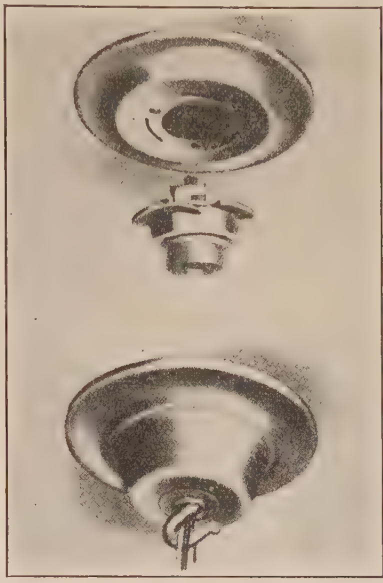

Fig. 3—Elexit Ceiling Outlet, Plug and Canopy for Suspended Elexilier

ture made in Philadelphia be installed by a layman in St. Louis in an elexit, the parts of which may have been made in Chicago, Schenectady or Bridgeport.

COLOR TEMPERATURE AND ITS RELATION TO THE QUALITY OF LIGHT

By W. E. Forsythe
Nela Research Laboratory

In a paper[1] presented before the Illuminating Engineering Society in October 1921 at Rochester, the subject of color temperature and its relation to the quality of the emitted light for a number of different light sources was discussed. There it was shown that by the use of the color temperature of a light source a number is given which expresses the quality of the light of those sources to which the method applies.

When any substance, in general and particularly a black body is heated, the light at first given off is a dark red and as the temperature is increased it becomes a lighter red and then tends to become more white until if it could be heated to a temperature of approximately 5600 deg. K. it would match sunlight color.

The color temperature of a radiating body is defined as the temperature at which it is necessary to operate a black body in order that the light emitted from the black body at this temperature may have the same integral color as that of the source studied. By black body is meant a body that will absorb all the radiation that it receives, that is to say, it will neither reflect nor transmit any of the incident radiation. It can be shown that the radiation from such a body is a function of the temperature only. There is no known

1. Hyde and Forsythe, *Transactions* I. E. E., Vol. XVI, p. 419.

substance that has strictly this property, the nearest approach being probably untreated carbon. A hollow cavity with walls at a uniform temperature has been shown to possess the properties of a black body. If a small opening is made in the wall of this uniformly heated cavity, the radiation issuing from the hole will obey the laws of black body radiation.

The color temperature of a source can be very accurately compared with that of a standard by the use of a Lummer-Brodhun contrast photometer. To do this the source studied is mounted on one side of the photometer and a comparison lamp on the other side. Suppose that at the start the comparison lamp is too low, then when there is a brightness match, the trapezoid that is illuminated by the comparison lamp will appear reddish as compared with the other one which appears bluish. If now the voltage applied to the comparison lamp is raised a small amount and at the same time the photometer moved so that there is an intensity match, as observed in the photometer, the comparison trapezoid will appear less reddish than before. By repeating this process the comparison lamp can be very accurately matched in color with the source being studied. The source studied is now to be removed and replaced with the standard lamp and the process repeated just as before excepting that in this case the voltage applied to the standard lamp is to be varied and the comparison lamp kept constant at the voltage above obtained. Thus the standard lamp can be brought to a color match with the comparison source. It has been found experimentally that a black body and most radiating solids can thus be color matched. Also most of the flames that have been used as light sources can be color matched with the black body. However, the Welsbach gas lamp and the sources that do not have a continuous spectrum cannot be so compared.

Experienced observers by taking the average of three or four readings obtain values of voltage for the color match of two lamps that agree to within about one-half volt, when the lamp is operated at about normal voltage. This difference in voltage corresponds to a difference in color temperature of about 4 deg. K. This small change in color temperature at this temperature (about 2400 deg. K.) corresponds to a difference of about 0.6 per cent in relative energy between the red ($\lambda = 0.665\mu$) and the blue ($\lambda = 0.467\mu$) This is much better than the accuracy generally claimed in spectral distribution work.

A comparison of the color temperatures of some of the common illuminants will illustrate the simplicity and significance of this method. Thus the color temperature of the ordinary sperm candle is 1930 deg. K. (1657 deg. cent. + 273 deg.), that of the 4-watt-per-candle carbon lamp 2080 deg. K., that of the 1.25-watt-per-candle vacuum tungsten lamp 2400 deg. K., that of the 500-watt, 0.72-watt-per-spherical-candle tungsten lamp 2880 deg. K., and that of the sun as observed at the earth's surface about 5600 deg. K. With a few such fixed points in mind one may readily place any illuminant in regard to the quality of its light if its color temperature is given.

In the following table are given the color temperatures for a definite lumens per watt for a number of different types of tungsten lamps:

Lamp	Specific Output Lumens per watt	Color Temperature Degrees Kelvin
40 watt Type *B* (vacuum)...	10.0	2500
100 " Type *C* (gas filled)..	12.6	2740
500 " Type *C* (gas filled)..	17.4	2880
1000 " Type *C* (gas filled)..	20.3	2985
1000 " Stereopticon........	24.2	3175
900 " Movie............	27.3	3220

INSTITUTION OF ELECTRICAL ENGINEERS JUBILEE MEETING

During the latter part of February, meetings were held in commemoration of the first gathering of the Society of Telegraph Engineers which subsequently became the Institution of Electrical Engineers. The program consisted of lectures and addresses bearing on the early history and developments in electrical engineering and many interesting reminiscences of the pioneers in this field were recounted. Among a long list of speakers were Dr. Fleming, Sir Charles Parsons, Dr. S. Z. deFerranti, Mr. J. Swinburn, Mr. J. H. Patchell, Mr. J. E. Kingsbury, Mr. C. H. Wordingham and Mr. Campbell Swinton.

Commenting upon the many pioneers in the electrical field who are still leading and active members of the profession, *Engineering*, London, states:

"The fact that the Institution of Electrical Engineers has a nearer knowledge of the history of the profession for which it stands than has perhaps some of the other engineering institutions, is illustrated by the long list of members who are available to contribute to the account of earlier days. The reason for this is the obvious one that the whole history of the development of electrical engineering lies well within the limits of a present lifetime. The first Atlantic cable was laid only sixty-six years ago. The incandescent lamp was invented only forty-four years ago, and the first telephone exchange dates from about the same time. The amazing present development from these recent beginnings has resulted in the growth of the Institution of Electrical Engineers to a membership of 10,000 and to an authority which it is difficult to assess. The relatively brief period covered by the history of electrical engineering results in the total of 10,000 members, containing many personally familiar with the first steps. This condition clearly cannot continue indefinitely, and the commemoration meetings of this week will bring together and place in permanent form a collection of reminiscences and historical footnotes which will always be of interest and may not infrequently be of service in the developments which will be the heritage of a later generation."

Magnetic Flux Distribution in Transformers

BY KARL B. McEACHRON
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It is customary when discussing magnetic leakage in the transformer to consider the primary and secondary windings as having a counter e. m. f. induced by a flux surrounding the coil and having the core for a part of its path. This leakage flux is frequently represented by closed lines.

Since the main flux is also represented by closed lines in the core, apparently two fluxes are to be found in the core under a given coil, namely, the leakage flux and the main flux.

The main flux is the flux found in the core at a point not under either the primary or secondary winding, and has been commonly considered as being the flux which causes the secondary induced voltage.

If the leakage fluxes have a separate existence, i. e., if they are to be represented by closed lines, then the flux along the edges of the core would consist largely of leakage lines while that to be found in the middle portion of the core would be the main flux. Since these fluxes are out of phase with one another it should be possible to identify them if they are present as separate fluxes.

Using a simple test core-type transformer, provided with belt exploring coils under both the primary and secondary windings, data concerning the magnitudes and phase positions of the fluxes in different sections of the core were secured.

The results show that leakage fluxes do not exist as separate fluxes in the core. It is also shown that the primary and secondary induced voltages are equal to the primary and secondary terminal voltages diminished and increased respectively by the corresponding I R drops.

Some difference of opinion exists among engineers concerning the distribution of lines of magnetic flux in a transformer operating under load. Many writers, and in fact practically all of the text-books, in the treatment of the transformer, divide the so-called leakage reactance into two parts, one part being due to the primary ampere turns, and the other to the secondary ampere turns. This notion of the leakage reactance assumes that a secondary leakage flux exists, and in many cases is taken as being equal to the leakage flux of the primary. Others believe that the leakage flux actually to be found in a transformer is the result of the combination of primary and secondary m. m. fs. rather than a combination of the fluxes produced by each m. m. f. acting separately.

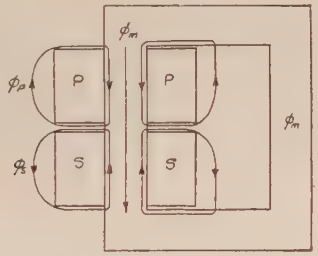


FIG. 1

ϕ_m = main flux.
ϕ_p = primary leakage flux.
ϕ_s = secondary leakage flux.

OBJECT OF THE PAPER

In order that the experimental evidence might be secured, a small transformer was built up, and the flux distribution studied. It is the purpose of this paper to describe this investigation, and point out some conclusions which may be drawn from the results obtained.

EXPERIMENTAL APPARATUS: THE TRANSFORMER, INSTRUMENTS AND GENERATOR

By reference to Figs. 1 and 2, which are drawn in accordance with the two theories outlined above, it will be seen that the difference in the flux distribution is to be found in the space underneath the secondary coil. The flux under the primary coil is the same according to either theory.

In order that the flux and its phase relations might be determined, it was decided to make use of belt coils similar to those described by Kennelly and Alger in their paper on "Magnetic Flux Distribution in Annular Steel Laminae" before the Institute in 1917. The simple type of transformer shown in Figs. 1 and 2 was chosen, and belt coils were threaded through holes bored in the core underneath the primary and secondary coils.

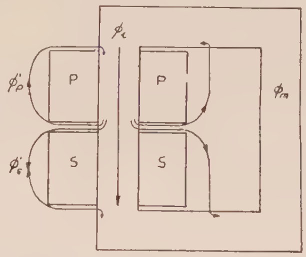


FIG. 2

ϕ_i = flux which threads both primary and secondary.
ϕ_s' = flux which threads primary, but which passes outside secondary.
ϕ_p' = flux which threads primary only.

The core was built up out of straight laminations 8 in. (20.3 cm.) long, 2 in. (5.08 cm.) in width, and having a thickness of 0.014 in. (0.455 mm.). These laminations were cut from a good grade of silicon transformer steel. The punchings were all carefully annealed after cutting, and the oxide thus formed was depended upon to furnish sufficient insulation between sheets. The core data are given herewith.

To be presented at the Spring Convention of the A. I. E. E., Chicago, Ill., April 19-21, 1922.

Number of laminations......	=	128
Depth of core..............	=	1.875 in. (4.76 cm.)
Thickness of lamination.....	=	0.014 in. (0.355 mm.)
Cross-section of core........	=	3.375 sq. in. (21.7 sq. cm.)
Stacking factor.............	=	0.9
Weight of core..............	=	24.2 lb. (10.52 kg.)
Number of air gaps.........	=	4

Six holes, 0.154 in. (0.391 cm.) in diameter, were drilled through the core in the locations shown in Fig. 3. They were carefully reamed out to size, all burrs removed, and the surfaces painted with shellac. Through these holes, 40 turns of No. 34 B & S enameled

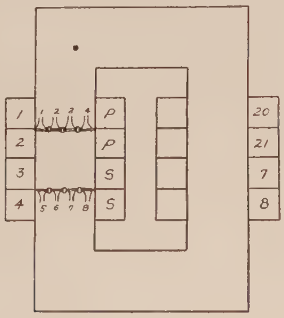


Fig. 3

Core area diminished by the area of the belt coil holes = 2.9 sq. in. (16.7 sq. cm.)

All transformer coils have 200 turns each, and are wound with No. 16 B and S wire.

Coils 7 and 8 were used as tertiary coils. Coils 20 and 21 were not used in this investigation.

Resistances of transformer coils at 25 deg. cent:

(1) = 0.772 ohm	(4) = 0.769 ohm
(2) = 0.767 "	(7) = 0.775 "
(3) = 0.771 "	(8) = 0.782 "

Belt coil area (cm.)^2 :

(1) 4.59	(5) 4.43
(2) 3.80	(6) 3.77
(3) 3.74	(7) 3.81
(4) 4.67	(8) 4.76

wire were wound, forming altogether eight belt coils, with 80 wires per hole. The belt coils were numbered from 1 to 8, numbers 1 to 4 being under the primary coil.

The positions of the various coils when placed upon the core are shown in Fig. 3. As seen in the figure, the primary and secondary each consisted of two coils, with the belt coils under the middle of each winding. Each coil before taping was one inch square in cross-section.

After canvassing the list of available instruments, it was decided to connect a low-reading milliammeter in series with the belt coil under test and a sensitive element on the oscillograph. The ammeter has a full-scale deflection of 0.030 ampere, a reactance of from 0.25 to 0.27 henry and a resistance of 304.5 ohms. To prevent the current through the belt coil in use from distorting the flux, it was necessary to provide a similar load for each of the three belt coils not under test. To do this three coils were each wound to an inductance of 0.25 henry and a resistance of 300 ohms. The winding data for these coils were obtained from the curves given by Brooks in Bulletin 53, University of Illinois, Engineering Experiment Station.

To make changes in connections easily and quickly, the three loading coils and the test circuit were connected to telephone plugs as shown in Fig. 4.

An alternator rated at 7.5 kv-a., 110 volts, 60 cycles, furnished practically a sine wave for the test.

Method of Test and Results

Tests were made with the transformer operating under the following conditions:

(a) No-load.

(b) Secondary short-circuited, with impedance volts supplied to the primary.

(c) Non-inductive load.

(d) Inductive load.

A magnetization curve was taken, and a point chosen on it below the knee of the curve so that the exciting current would not show distortion due to changes in permeability.

Oscillograms showing the phase relation of the belt coil current and the impressed voltage were taken. The voltage wave, designated by the letter e on the oscillograms, was used as a reference for determining the position of the current flowing through the particular belt coil under test. In each case while the current in one belt coil was being investigated, the other three belt coils were connected to their respective loading coils.

On account of lack of time the usual method of taking oscillograms was not followed; instead bromide paper was placed on the viewing screen and exposed for a period of about 10 seconds. The oscillograms appearing in this paper are from photographs of these prints.

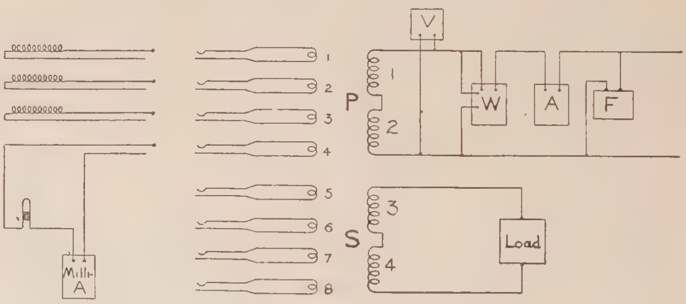


Fig. 4

Using the belt coil ammeter readings, and the constants of the ammeter circuit, the voltage induced in each belt coil was calculated. From these voltages the fluxes linking the various belt coils were obtained.

Using the calculations given in the appendix based upon the no-load and impedance test data, the phase positions and magnitudes of the various voltages were calculated. The data obtained from the belt coils are compared in each case with the results obtained by calculation.

The vector diagrams are drawn to scale using the calculated data.

(*a*) *No-Load Conditions.* Core loss test data: 115 volts, 0.08 ampere, 2.47 watts, 61-cycle frequency.

TABLE I.

Results of Tests Made Under No-Load Conditions.

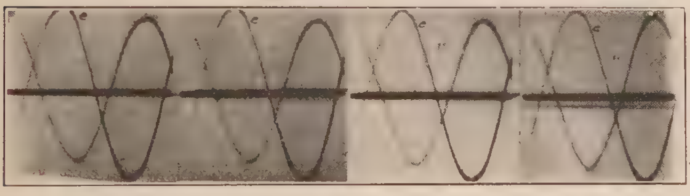
Belt Coil No.	Belt Coil Amperes	Flux per sq. cm. (B'_{max})	Degrees Displacement	Average B'_{max}	Average Angle
I	II	III	IV	V	VI
1	0.0086	5680	40		
2	0.0084	6690	40	6230	37 lag
3	0.0086	6950	35		
4	0.0088	5600	32		
5	0.00835	5640	35		
6	0.00835	6610	33	6070	33 lag
7	0.0085	6640	33		
8	0.0086	5390	32		

Fluxes in column (III) are calculated from column (II) and show the maximum value of flux threading the belt coil turns.

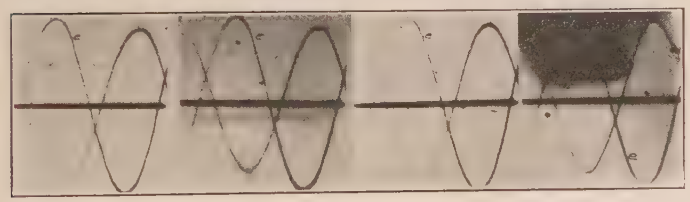
Angles in column (IV) are taken from the oscillograms, and have been diminished by 180 degrees since an applied voltage rather than an induced voltage was used as a reference.

The flux density corresponding to the impressed voltage (115) is 6240 lines.

The lag angles shown in Table I show but little variation, and an angle of 33 degrees will, therefore, be subtracted from the angles measured on the oscillograms. This correction when applied to the position of the belt coil current wave, should give the approximate location of the voltage induced in the belt coil winding.



1 2 3 4
Primary Belt Coils



5 6 7 8
Secondary Belt Coils

FIG. 5—NO-LOAD CONDITIONS—SHOWING POSITIONS OF BELT COIL CURRENTS
e = reference voltage

The flux density given by the table is seen to be greater in the middle of the core than on either side. This condition is true for both the primary and secondary, the primary being slightly greater in value.

It will be noticed in all the following tests, that the flux distributes itself across the core in about the same manner no matter what the condition of loading may be.

(*b*) *Impedance Conditions.* (*Secondary Short-Circuited.*) Test data: Impedance volts (E_p) = 60 volts, primary current (I_p) = 4 amperes, input watts (W_p) = 51.3 watts, tertiary volts (E_m) = 24 volts, frequency (f) = 60 cycles.

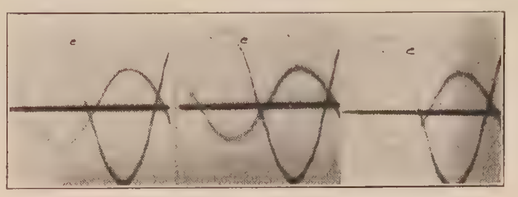
TABLE II.

Results of Belt Coil Tests Made Under Impedance Conditions.

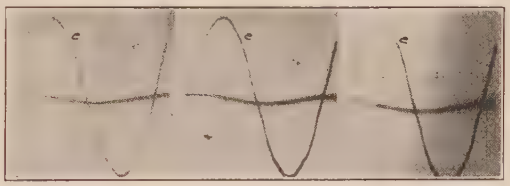
Belt Coil No.	Belt Coil Amperes	B'_{max}	Degrees Displacement	Corrected Angle	Average B'_{max}	Average Angle
I	II	III	IV	V	VI	VII
1	0.0046	3040	24 lag	9 lead		
2	0.0045	3580	22 "	11 "	3330	8 lead
3	0.0045	3640	27 "	6 "		
4	..	..	..	..		
5	..	310*	98 lag	65 lag		
6	..	370*	98 "	65 "	340	66 lag
7	..	370*	100 "	67 "		
8	..	..	..	..		

Angles in column (V) are equal to those in column (IV) diminished by 33 degrees.

*These fluxes were calculated from the amplitude of the current wave, the oscillograph element having been previously calibrated.



1 2 3
Primary Belt Coils



5 6 7
Secondary Belt Coils

FIG. 6—IMPEDANCE CONDITIONS—SHOWING POSITIONS AND MAGNITUDES OF BELT COIL CURRENTS

e = reference voltage.

Voltages and flux densities, calculated (see appendix) from the constants of the transformer, and the test data, are given in Table III.

TABLE III.

Voltages and Flux Densities Obtained by Calculation.
(Impedance Conditions)

Voltage	B_{max}	B'_{max}	Degrees Displacement
I	II	III	IV
$\overline{E_p} = 60 + j\,0$			
$\overline{E_p'} = 58.7 + j\,6.0$	2530	3290	6 lead
$\overline{E_m} = 23.9 - j\,1.6$	1030	1470	4 lag
$\overline{E'_s} = -1.32 + j\,6.1$	260	340	76 lag
$\overline{E_s} = 0.0 + j\,0.0$			

$\overline{E_p}$ = primary impressed voltage. $\overline{E_p'} = \overline{E_p}$ diminished by $\overline{I_p R_p}$.

$\overline{E_m}$ = voltage induced by main flux, i. e., flux in parts of the core not under either primary or secondary coils.

$\overline{E_s}$ = secondary terminal voltage. $\overline{E_s'} = \overline{E_s}$ increased by $\overline{I_s R_s}$.

B_{max} = normal flux density in the core.

B'_{max} = normal flux density in the core based on undiminished cross-section of core.

From a comparison of the flux densities and angles shown in columns VI and VII of Table II with the corresponding values in columns III and IV of Table III, it is clear that the voltage induced in the primary is $\overline{E}_p'$ and that the secondary induced voltage is $\overline{E}_s'$. $\overline{E}_m$ has been commonly referred to as the voltage induced in the secondary winding, but the data show that the flux found under the secondary winding is only sufficient to induce a voltage equal to the secondary $I\ R$ drop.

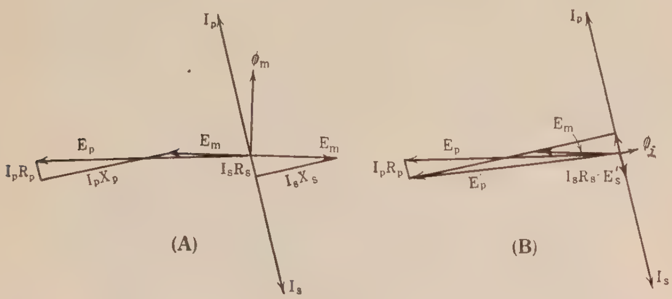


FIG. 7

No trace of the leakage flux is found in the core under the secondary as a separate flux, the distribution across the core being similar to that at no-load, and the angle of lag practically constant across the core. The only flux found under the secondary coils is that sufficient to overcome the secondary $I\ R$ drop.

The vector diagram shown in Fig. 7A, is drawn in the manner usually found which assumes that there is an actual reactance drop in both primary and secondary, and that the induced voltage is equal to E_m. Another diagram based upon the idea that the induced voltages are those found in this test is shown in Fig. 7B.

Either method will give the same numerical results, but it is to be remembered that the leakage flux and the main flux cannot exist in the core as separate and independent fluxes. Further discussion of the two methods will be found later in this paper.

(c) *Non-Inductive Load.* Test data: $E_p = 115$ volts, $I_p = 3.82$ amperes, frequency = 60 cycles.

TABLE IV.

Results of Belt Coil Tests Made with Non-Inductive Load

Belt Coil No.	Belt Coil Amperes	B'_{max}	Degrees Displacement	Corrected Angle	Average B'_{max}	Average Angle
I	II	III	IV	V	VI	VII
1	0.0082	5400	18 lag	15 lead		
2	0.0080	6380	18 "	15 "	6020	14 lead
3	0.0080	6500	20 "	13 "		
4	0.0085	5500	20 "	13 "		
5	0.0067	4600	54 lag	21 lag		
6	0.0068	5460	54 "	21 "	5050	20 lag
7	0.0069	5500	52 "	19 "		
8	0.0070	4450	51 "	18 "		

TABLE V.

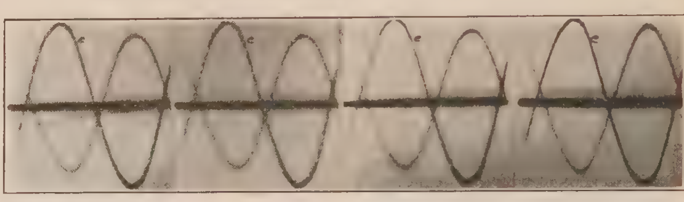
Voltages and Flux Densities Obtained by Calculation (Non-Inductive Load)

Voltage	B_{max}	B'_{max}	Degrees Displacement
I	II	III	IV
$E_p = 115 + j\,0$			
$E_p' = 109.8 + j\,2.86$	4800	6240	1 lead
$E_m = 93.3 - j\,26.8$	4240	5510	16 lag
$E_s' = -82.7 + j\,46.0$	4120	5360	29 lag
$E_s = -77.4 + j\,43.2$			

A comparison of Tables IV and V shows that the voltage induced by the flux under the primary corresponds to E_p' while the flux under the secondary induces a voltage of E_s'. While the numerical values do not check as closely as might be desired, yet they are sufficiently close to lead to the conclusion given.

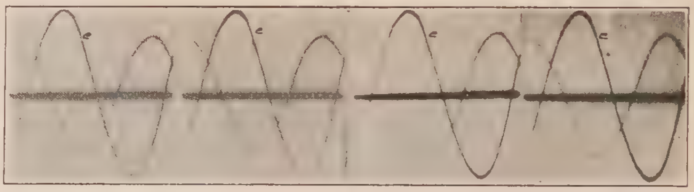
(d) *Inductive Load.* Test data: $E_p = 115$ volts, $I_p = 4.03$ amperes, frequency = 60 cycles.

Load characteristics: $E_s = 54$ volts, $I_s = 4.04$ amperes, $W_{load} = 50.6$ watts.



1 2 3 4

Primary Belt Coils



5 6 7 8

Secondary Belt Coils

FIG. 8—NON-INDUCTIVE LOAD—SHOWING POSITIONS OF BELT COIL CURRENTS

e = reference voltage

TABLE VI.

Results of Belt Coil Tests (Inductive Load)

Belt Coil No.	Belt Coil Amperes	B'_{max}	Degrees Displacement	Corrected Angle	Average B'_{max}	Average Angle
I	II	III	IV	V	VI	VII
1	0.0087	5740	20 lag	13 lead		
2	0.0083	6620	20 "	13 "	6250	13 lead
3	0.0081	6580	..	..		
4	0.0088	5700	..	..		
5	0.0040	2750	29 lag	4 lead		
6	0.0040	3210	29 "	4 "	2950	3 lead
7	0.0040	3160	31 "	2 "		
8	0.0040	2530	31 "	2 "		

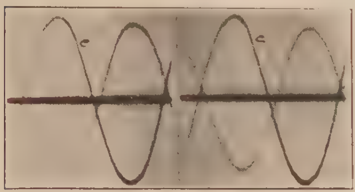
TABLE VII.

Voltages and Flux Densities Obtained by Calculation (Inductive Load)

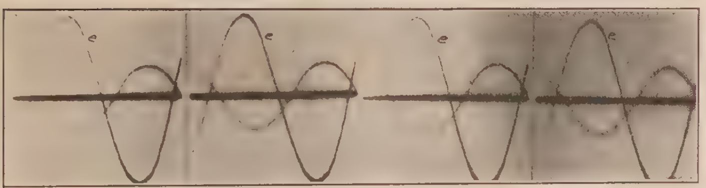
Voltage	B_{max}	B'_{max}	Degrees Displacement
I	II	III	IV
$E_p = 115 + j\,0$			
$E_p' = 113.6 + j\,6.11$	4870	6330	3 lead
$E_m = 78.4 - j\,1.88$	3360	4370	1 lag
$E_s' = -55.6 + j\,6.98$	2390	3110	7 lag
$E_s = -54.2 + j\,0.86$			

Discussion

The flux threading the belt coils was found in every case to be sinusoidal. The reluctance of the four air gaps in the core effectively prevented the distortion noted by Kennelly and Alger in their paper previously referred to.



1 2 3 4
Primary Belt Coils



5 6 7 8
Secondary Belt Coils

FIG. 9—INDUCTIVE LOAD—SHOWING POSITIONS OF BELT COIL CURRENTS

e = reference voltage.

All the evidence of the tests made goes to prove that the voltage induced in the primary winding is the supplied voltage diminished vectorially by the primary $I\,R$ drop, and that the voltage induced in the secondary winding is equal to the secondary terminal voltage increased vectorially by the secondary $I\,R$ drop. The flux usually referred to as the main flux, and so called in this paper, does not alone produce the induced voltage in either the primary or secondary.

Practically all of the flux found in the ordinary low-voltage transformer, as for example the type generally used for distribution, is produced by the ampere turns of the primary. The ampere turns of the secondary modify the flux produced by the primary, but do not produce any flux which enters the core. The secondary winding may produce flux which does not enter the core, and this will be the case with the higher voltage coils where the distance between coils and core becomes quite large.

It would seem, in view of the fact that the leakage fluxes do not have a separate and independent existence in the core, that it is better not to represent such fluxes by closed lines in the core, because the use of the line conveys the idea that the leakage flux occupies a place close to the edge of the core, thus crowding the main flux to the middle of the core. The conception of lines of force is merely for convenience, and in cases where two or more m. m. fs. not in the same phase are acting upon a common part of the core, an altogether wrong conclusion may be arrived at, if the idea of lines is adhered to closely.

A figure (Fig. 10) suggested to the writer by Prof. Alfred Still, of Purdue University, will perhaps serve to make the presentation of what occurs in the core more accurate than the diagrams as usually drawn. The main flux is represented by three arrows showing the direction of the m. m. f. of the primary winding. Under the primary winding four arrows are found, indicating that the primary leakage flux is out of phase with the three arrows representing the main flux. This flux, and in fact all of the fluxes in the core may be

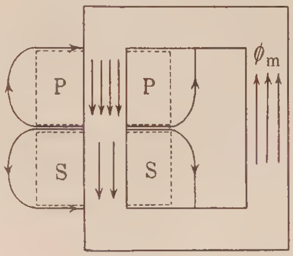


FIG. 10

considered as spreading across the core in the same manner as when no current is flowing in the secondary winding. Under the secondary winding the flux indicated by the two arrows is the vectorial difference of the four arrows under the primary, and the four arrows representing the leakage.

The calculation of the leakage paths has always nelgected the path in the iron, and since the air paths shown in the figure have not been changed, the method of calculation and the numerical results obtained therefrom are not affected by this investigation.

Conclusion and Summary

This investigation has shown that for the simple type of transformer investigated the leakage fluxes are not to be found as separate fluxes under the primary and secondary coils. Thus the method of representing the leakage fluxes so commonly used in text-books dealing with transformers in which the leakage fluxes are represented by lines in the same part of the core with other lines out of phase with them, does not picture a condition which actually exists.

It has also been shown that the voltage induced in the primary winding is equal to the supplied e. m. f. diminished by the $I\,R$ drop, and that the secondary

induced voltage is equal to the secondary terminal voltage increased by the secondary $I R$ drop.

The writer wishes to express his appreciation to the members of the Staff of the School of Electrical Engineering at Purdue University, who have taken a lively interest in the matter and who have offered many suggestions of value. Especial thanks are due to Prof. Alfred Still, who has followed the work closely, and under whose general supervision the thesis,[1] of which this is an abstract, was conducted.

Appendix

Calculation of Fluxes from Belt Coil Ammeter Readings

Measured inductance of ammeter = 0.25 henry.

Resistance of circuit including ammeter, belt coil, oscillograph and connections = 311 ohms.

Then $\sqrt{(311)^2 + \overline{(377)(0.25)}^2} = 325$ ohms impedance at 60 cycles.

The e. m. f. induced is:

$4.4 f N \phi 10^{-8}$ and equals $325 I$,

The maximum flux density is then $\dfrac{325 I 10^8}{4.4 A + 40}$

where A = belt coil area, f = frequency, I = belt coil current in amperes, 40 = turns per belt coil.

Calculations for the Different Conditions of Loading

The following list of symbols will be used.

E_p = Voltage impressed on the primary.
E_p' = Voltage induced in the primary winding.
E_m = Voltage induced by the main flux in the tertiary coil.
E_s = Secondary terminal voltage.
E_s' = Voltage induced in the secondary winding.
I_p = Primary current.
I_s = Secondary current.
W_p = Watts input to primary.
W_{load} = Watts output of secondary.

Test (b) Impedance Conditions: Calculation of E_m. Test data: $E_p = 60$, $I_p = 4$, $E_s = 0$, $E_m = 24$, $W_p = 51.3$.

Let $E_m = e + j e'$. Assuming that $E_p = 60 + j 0$ then the primary current $I_p = 4\ (0.214 - j\,0.976) = 0.856 - j\,3.9$.

The voltage usually called the primary $I X$ drop may be represented by $a\,(0.976 + j\,0.214)$, where a is its real value in volts.

The primary $I R = 1.54\,(0.856 - j\,3.9) = 1.317 - j\,6.0$

Then $E_p' = (60 + j\,O) - (1.317 - j\,6.0)$
$= 58.68 + j\,6.0.$

Also $(e + j\,e') + a\,(0.976 + j\,0.214)$
$= 58.68 + j\,6.0$

and $(0.976\,a + e) + j\,(0.214\,a + e')$
$= 58.68 + j\,6.0$

These are identically equal, and therefore,
$0.976\,a + e = 58.68$, and $0.214\,a + e' = 6.0$ also, (1)
$\sqrt{e^2 + e'^2} = 24$, since from the data, $E_m = 24$. (2)

Eliminating a between the equations in (1), substituting in (2) and solving for e' we have

$e' = 11.36$ or -1.60.

From the vector diagram it may be seen that -1.60 is the correct value. Substituting this value in equation (2) and solving we obtain,

$e = 23.95.$

Thus $E_m = 23.95 - j\,1.60.$

Primary I X. For use in the following calculations it will be useful to find value and phase position of the primary $I X$:

It is $(58.68 + j\,6.0) - (23.95 - j\,1.6) = 34.73 + j\,7.6.$

The primary reactance is then

$$\frac{34.7 + j\,7.6}{0.856 - j\,3.90} = 0 + j\,8.88$$

The primary resistance is

$$= \frac{1.317 - j\,6.0}{0.856 - j\,3.90} = 1.54 + j\,0.$$

The primary impedance is therefore $1.54 + j\,8.88$. The total transformer impedance is then

$$\frac{60 + j\,0}{0.856 - j\,3.90} = 3.2 + j\,14.6 \qquad (3)$$

Since the ratio of the transformer is 1 to 1, the secondary impedance may be taken as the difference between the total and that in the primary. The secondary impedance is then $1.66 + j\,5.72$. The measured value of the secondary resistance was 1.54.

This check is quite satisfactory when it is remembered that the value of R depends upon the wattmeter reading. The fact that the core loss was neglected tends to make the resistance come out higher than it should. The secondary impedance will therefore, be taken as $1.54 + j\,5.72$.

Then $E_s' = (-\,23.95 + j\,1.60) - (0.855 - j\,3.9)\,(1.54 + j\,5.72) = 1.32 + j\,6.1.$

Test (c) Non-Inductive Load. Test data: $E_p = 115$, $I_p = 3.82$.

Let $E_p = 115 + j\,0$.

Using (3) we have,

$$I_p = 3.82 = \frac{115}{\sqrt{R^2 + (14.6)^2}} \text{ or } R = 26.4 \text{ ohms.}$$

then

$$I_p = \frac{115 + j\,0}{26.4 + j\,14.6} = 3.35 - j\,1.86.$$

$$E_p' = (115 + j\,0) - (1.54 + j\,0)\,(3.35 - j\,1.86) = 109.8 + j\,2.86.$$

1. Graduate Thesis, "Investigation of Leakage Fluxes in Transformers," by K. B. McEachron, Purdue University, 1920.

$$E_m = (109.8 + j\,2.86) - (O + j\,8.88)\,(3.35 - j\,1.86) = 93.3 - j\,26.84.$$

$$E_s' = (-\,93.3 + j\,26.84) - (O + j\,5.72)\,(-\,3.35 + j\,1.86) = -\,82.68 + j\,46.0.$$

$$E_s = (-\,82.68 + j\,46.0) - (1.54 + j\,O)\,(-\,3.35 + j\,1.86) = -\,77.5 + j\,43.14.$$

The voltage E_s will be found to be in phase with the secondary current.

Test (d) Inductive Load. Test data: $E_p = 115$, $I_p = 4.03$, $E_s = 54$, $I_s = 4.04$, $W_{load} = 50.6$.

The resistance and reactance of the load respectively, are:

$$R_l = \frac{50.6}{(4.03)^2} = 3.1 \text{ and } X_l = \sqrt{\left(\frac{54}{4.03}\right)^2 - 3.1^2} = 13$$

Total resistance including load $= 3.08 + 3.1 = 6.18.$
Total reactance including load $= 14.6 + 13.0 = 27.6$

$$\text{Total } I_p = \frac{115 + j0}{6.18 + j\,27.6} = 0.889 - j\,3.97.$$

$$E_p' = (115 + j\,0) - (0.889 - j\,3.97)\,(1.54 + j0) = 113.6 + j\,6.11.$$

$$E_m = (113.6 + j\,6.11) - (0.889 - j\,3.97)\,(0 + j\,8.88) = 78.4 - j\,1.88.$$

$$E_s' = (-\,78.4 + j\,1.88) - (-\,0.889 + j\,3.97)\,(0 + j\,5.72) = -\,55.6 + j\,6.98.$$

$$E_s = (-\,55.6 + j\,6.98) - (-\,0.889) + j\,3.97)\,(1.54 + j\,0) = -\,54.2 + j\,0.86.$$

The Superpower System—I

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Review of the Subject.—*The paper deals with the essential elements of the superpower plan and discusses the effect of a cheaper and more adequate power supply upon the industrial activity of the United States. The economies effected by the electric utility systems of the country in the past are brought out, while the need for greater co-ordination between the electric utilities through some such agency as superpower systems is emphasized.*

The present power production facilities within the superpower zone form an important element of the proposed superpower system. The plan does not call for the complete scrapping of existing electric utility plants or transmissions, but uses these to a very large extent as the nucleus of the system. The effect of amortizing less efficient steam-electric plants is to materially increase the resulting economy of the balance of existing plants, which, with proposed new water power developments, are used to carry the peak load impressed upon the system, permitting the base load steam-electric plants to operate at very high capacity factors with resulting low production costs. The location of base load steam-electric plants in the bituminous coal-mining region is found to be uneconomical at the present time, but the location of large stations in the anthracite region is found to yield very attractive returns. The use of process fuel is not recommended under present conditions, but provision is made in the station designs for the use of such fuel at a later date should it prove profitable.

The Superpower Report sets forth principles rather than a detailed analysis of a particular situation and this report must be followed by detailed studies of different sections of the country, taking into consideration the local conditions which must be provided for.

CONTENTS

INTRODUCTION

When Mr. William S. Murray discussed the advantages that should accrue from the coordination of the power systems along the Atlantic seaboard, with Secretary of the Interior Lane, the country was just emerging from the World's War, but it was still in the height of its industrial prosperity with its corresponding power shortage. The lack of an adequate power supply was then serious and resulted in slowing up the production of needed munitions and war supplies, and the subject, therefore, was at that time very keenly appreciated both by Government officials and by the managers of the electric utility industry.

Presented at a meeting of the Washington Section of the A. I. E. E., Washington, D. C., January 10, 1922.

As a result of Mr. Murray's efforts, the Superpower Survey was authorized by Congress in 1920 and was placed under the direction of Dr. George Otis Smith, Director of the U. S. Geological Survey. Too much credit cannot be given to Dr. Smith for his great interest in the work and for the unstinted aid which he extended to the engineering staff directly engaged in the preparation of the report.

INDUSTRIAL CONDITIONS IN SUPERPOWER ZONE

The area selected for the study is the most intensely developed industrial district in the United States, and while it contains but 2 per cent of the land area of the country, 22 per cent of the country's entire population dwells within its borders, and the industries located therein produce more than 40 per cent of the total value of manufactured products of the entire country.

The Superpower Plan

At the annual meeting of the American Society of Mechanical Engineers last December, Professor Breckenridge, Chairman of the Advisory Board of the Superpower Survey, briefly summed up the essential elements of the superpower plan so well that I will repeat them now:

(a) The generation of power in steam-electric plants of large capacity and of the highest economy.

(b) The location of these steam-electric plants advantageously with relation to coal mines, condensing water, load centers and coal distribution.

(c) The extensive development of the hydroelectric resources of the area.

(d) Construction of trunk transmission lines for the interconnection of the generating stations, both steam and water, with the principal load centers of the zone.

(e) The making available of a cheap, reliable and adequate power supply to the heavy traction railways by means of the interconnected system of power plants and trunk transmission lines.

(f) A unified system of control in charge of a power dispatcher.

(g) The delivery of the primary power to the electric utilities within the zone.

(h) The local distribution of all energy by the electric utilities.

While the region selected was taken because of its intense industrial development, this same principle can be applied to any other section of the country, and to the entire country, with results similar to those that will accrue to the selected district along the Atlantic seaboard.

The financial depression through which we have just passed has removed the immediate necessity of intensive power development, but all signs point toward renewed industrial activity, and when this begins the lack of an adequate power supply will immediately be felt.

Increasing Economic Necessity of Superpower System

There is a reason why power and particularly cheap power will become of more and more importance to this country than has been the case in the past. Prior to the World's War, this country was a debtor nation, importing large amounts of manufactured articles for which we partially paid by the exportation of raw materials to Europe. Our own natural resources had been largely developed through the borrowing of foreign capital, so when the World's War broke out, we had a large trade balance standing against us. The World's War, however, has reversed our financial status. During the early periods of the war, we exported large amounts of munitions and war supplies to the various belligerents abroad and even before we entered the war, we had liquidated the adverse balance and had become a creditor nation. By our own entry into the war, we increased Europe's obligations to us so that upon its termination and that of the period immediately succeeding, Europe had become a debtor to this country to the extent of over thirteen billions of dollars.

The question as to how Europe will liquidate this debt is one of great concern to our ablest financiers. It is self-evident that the debt cannot be liquidated by gold, as today we own a very large proportion of all of the free gold available. It is probable that the larger part of this debt must be paid through goods, and our manufacturers therefore must be in a position to meet competition with these goods.

While England is paying her labor more pounds, France is paying her labor more francs and Germany is paying her labor more marks than they did prior to the World's War, the currencies in all of these countries are so much more inflated than they were prior to our entry into the World's War that their labor when compared to our own is even cheaper today than it was in 1914, and the problem of our manufacturers becomes that of being able to meet these relatively deflated foreign labor costs.

Again, our own needs can be supplied by some nine to ten months' employment of the production facilities we have now available in this country, and in order to keep those facilities at work, it is necessary for us to develop foreign markets for export which will throw us into competition with the cheap labor of Europe in those markets as well as in our own.

Power in connection with the competition of cheap labor, becomes of paramount importance. There is a definite and important relation between the amount of machine power used per wage earner and the value of the product he produces. Thus, while in 1899 we were using about two horse power per wage earner with a resulting annual value of product of $2400, by 1914 we had increased our machine power to 3.2 horse power per wage earner with corresponding increases in the value of his output to $3400 per annum. As yet there is no European country approaching this productivity per wage earner, but Europe learned much from us during the World's War, and our safe way to guard industry is by increasing the machine power available to each wage earner, thus supplementing our man power to such an extent that we can overbalance the low labor costs against which we must compete.

Present Economic Accomplishments of Electric Utilities

The electric utility systems of this country have been the foremost advocates of efficiency and since their inception, their history has been one of price reduction without a break until about 1918. The continual lowering of rates during that period by the electric utilities was made possible principally through the increased efficiency of operation, and even the increases in the rates granted during the past few years of high prices have not been at all in proportion to the increases in the prices of the commodities that go to make up their product.

The electric utilities are, however, beginning to reach the point of minimum cost for independent develop-

ment. The possibilities of large reductions in cost for the operation of existing power plants are not great. The independent development of water powers of the nature available to our Atlantic seaboard is restricted to developments of comparably small size and the interconnection between municipalities and even between companies under present arrangements yields little as an economic result except in insured reliability to service. In other words, we have come to a turning point where to do as they have been doing, the electric utilities must progress slowly and laboriously, but where, by changing their systems now serving individual municipalities or small sections to one serving immensely large areas through coordinated effort it means large returns to the public and to themselves. The Superpower Report can be in fact summed up as a prophetic study of what will happen if the utilities and the public cooperate for the coordination of the physical structures for all future construction. It is merely a more efficient expansion of past practise. The electric utility started out with the power plant serving one business block. It grew until it served a municipality and then it spread out to the suburbs, until finally today we find interconnected systems serving areas of many thousands of square miles.

The Superpower Report discusses the principles through which financial benefits, in respect to the future development of our power system, will accrue not only to the electric utility companies, but to the people as a whole. The time available for the study was limited and while unusual cooperation was extended by electric utilities, railroads and manufacturing companies, it was still impossible to treat of the subject except in general. Each local condition could not be specifically considered and before the actual construction required for the superpower system can be started, it will be necessary to enlarge upon the work done by the engineering staff of the Survey by making such a detailed study, that each of the local conditions can be met. This may result in certain modifications of the location for power plants, transmission lines and load centers, but it will in no way affect the principles established by the Superpower Report.

The Nucleus of the Superpower System

Fortunately, the nucleus of a superpower system is with us. We do not have to tear down the entire fabric erected at much expense and many years of labor; in fact, the nucleus in power stations alone amounts to 52 per cent of the capacity that would be required for a superpower system were it in operation by 1925.

The existing capacity in steam-electric plants within the superpower zone in 1919 was 4,000,000 kw., while that of hydroelectric plants was 452,000 kw., making a total of 4,452,000 kw., available for the service of this zone. Of this amount the engineers of the Superpower Survey determined that 3,255,000 kw., could be economically retained and incorporated into the system, and as a result nearly 80 per cent of the existing power plant capacity would continue to function and have continued useful life.

While theoretically the displacement of all of the existing steam-electric plants by new plants designed for the highest economy would result in a slightly lower cost for power to the zone, such a step would not be practical or desirable from the standpoint of construction, operation or financing.

Under the conditions of electric utility operation for 1919, the average capacity for steam-electric plants was approximately 10,000 kw. By the elimination of the smaller and less efficient of these plants, the average capacity of the plants retained was increased to 44,600 kw., and while all of the steam plants under the operating conditions of 1919 required about 2.73 lb. of coal per kw-hr., the steam-electric plants retained for incorporation into the superpower system under the same conditions would require but 2.1 lb. of coal per kw-hr., which is a saving in fuel of 23 per cent.

Steam-Electric Plants Proposed for Superpower System

The present steam-electric plants incorporated into the Superpower System were selected either for their economy of operation or because of their strategic location for voltage regulation or standby purposes.

The estimated reproduction cost of all power plants serving the superpower zone in 1919 was approximately $598,000,000, while the same value for these plants retained amounted to $418,000,000, or about 70 per cent of the investment then made in power plants. Because of their larger size, and the greater individual capacity of the generating units, the investment per kw. of capacity for these retained plants is materially lower than that for all of the plants existing in 1919.

The Superpower Report calls for discarding about 1,200,000 kw. of steam-electric plant capacity. To make the plan financially attractive, provision must be made for amortizing such discarded plant capacity over a period of years and debiting the fixed charges and amortization of such plants against the superpower system. This has been done and the superpower system has been charged with $39,600,000 per year, for 8 years, to provide for this expense.

The capacity of the retained steam-electric and hydroelectric plants forms an important portion of the entire capacity of power plants even in 1930, as it amounts to about 52 per cent of the total plant capacity for 1925 and about 40 per cent of the total capacity for 1930. Likewise, the investment amounts to 53 per cent of the total plant investment for 1925 and 41 per cent for 1930.

The economies to be effected by the superpower system are based upon the best use of each element going to make it up, so that the result will be the lowest possible cost obtainable. Accordingly, the retained

steam-electric plants are operated as peak load plants, operating at about 20 per cent annual capacity factor in 1925 and only about 17 per cent annual capacity factor in 1930.

The chief reliance of the superpower zone must be placed on coal-produced power, inasmuch as under the most favorable conditions of water power development, it is hardly possible that even by 1930, more than 21 per cent of the entire energy requirement could be produced by hydroelectric plants. The success of the plan, therefore, rests upon so constructing and so operating the system that the chief producers of power, that is, the base load steam-electric plants make each unit of energy at the lowest possible cost.

High capacity factor operation is the essential requirement for the cheap production of power in base load steam-electric plants and the entire structure of the superpower system has been built up to make it financially and physically possible to operate the base load steam-electric plants at high capacity factors. Base load steam-electric plants can, therefore, be designed to operate under loads having practically no daily variation in magnitude and but little variation in seasonal outputs, and under such conditions exceptionally good performances can be expected from them.

The policy of the engineers of the Superpower Survey was to hold to practises which had met the test of time, and accordingly the specifications for the conditions under which the base load steam-electric plants would operate do not present anything new or questionable. The steam pressure recommended of 300 lb. per square inch with a final temperature of 652 deg. fahr., and an absolute pressure at the turbine exhaust nozzle of one inch of mercury are conditions under which a number of steam-electric plants are operating today, both in this country and abroad, and the major troubles from such operating conditions have been determined and eliminated.

Owing to the variation in the cost for fuel throughout the zone and to the specific conditions under which each station would have to operate, three main classes of stations were provided; namely, those of very simple design with their boiler rooms equipped with stokers, but with no other heat-saving devices; those with boiler rooms equipped with stokers and economizers, and lastly, the very efficient type of station, utilizing stokers, economizers and air pre-heaters. Each of these groups was subdivided into a class for burning bituminous fuel and one for burning anthracite fuel.

The operating results predicted were arrived at after a very detailed study in which the manufacturers of equipment, the constructors of large power plants and the operating engineers of the larger utilities participated, and as a result of this cooperation by these best known authorities in the country, the coal rates and production costs predicted may be considered reliable and conservative.

The simple type of station burning bituminous coal, operating at 50 per cent annual capacity should attain a coal rate of approximately 1.23 lb. of coal per kw-hr., compared to approximately 2.0 lb. of coal per kw-hr. for the present steam-electric plants incorporated into the superpower system, resulting in a fuel saving of nearly 39 per cent. The saving in production cost under the same operating conditions by a superpower station, over that of the present power plants retained in the system, is an even greater percentage, because the unit costs of maintenance, labor and supplies and fixed charges are less, due to the smaller unit investment cost per kilowatt installed.

Base load steam-electric plants vary in size from 60,000 to 300,000 kw., and are each built up in multiples of 30,000 kw. units. The plants are located with especial reference to the delivery and cost of fuel and to the availability of condensing water. Another element entering into the location is that of the nearness of the market, but this is secondary to the other three requirements, inasmuch as they are the biggest factors in determining the lowest cost of power delivered to the market. One essential condition, however, in the location of superpower stations is that they should be outside of the limits of congested cities, so that there will be available to them ample room for adequate storage of at least six months supply and additional land area for the installation of a by-product plant should conditions later become such that the processing of fuel would reduce the cost of producing power.

Much interest was manifested by the public in respect to the location of large power plants in the coal mining region. This was not found to be economical under present conditions for the bituminous region, principally due to the lack of adequate supplies of condensing water in the bituminous coal fields located on the eastern slope of the Appalachian Mountains, but by the storage of water on the larger streams these conditions may be changed at some future date.

The production of power in the anthracite fields, however, proves to be most attractive, providing certain contingent conditions can be met. There is not at present a sufficient supply of the smaller sizes of anthracite coal to meet both the requirements of superpower plants located within the region and the natural market for such coal, but if a large number of anthracite mines were electrified, through which process they would receive large financial benefits, an adequate coal supply would be made available to superpower plants located in the anthracite region. Long-term coal contracts between the mine-owners and the owners of the superpower plants, at a price which is competitive with bituminous coal delivered at tidewater, is another condition that must be fulfilled to make the operation of such plants profitable.

From the results of conferences with anthracite mine operators, it is believed that such contracts are

entirely feasible and that arrangements can be made between the anthracite mine operators and the power plant owners, which will result in their mutual benefit.

The construction of base load steam-electric plants in the anthracite region can be made particularly attractive, due to the diversity of demand existing between that region and that along the seaboard between New York and Philadelphia. By connecting the proposed base load steam-electric stations in the anthracite region with the principal load centers along the coast, it would be possible to operate such plants at a very high capacity factor, thus producing power for about 5.7 mills per kw-hr. at their switchboards, even with the high prevailing costs for 1919, and this power can be transmitted to New York, and Philadelphia with a resulting cost of about 7.3 mills per kw-hr., which will show a saving of over 10 per cent of the cost to produce power in plants located in those load centers.

The use of hydroelectric plants on the Delaware River in connection with the proposed base load steam-electric plants for the anthracite region will be a large factor in providing cheap power, both to the industrial regions along the coast and the anthracite mining region.

Transmission Systems

The existing transmission systems owned by the electric utility companies are in most cases unsuitable for service as interconnecting transmission lines or trunk transmission lines, owing to their lack of adequate capacity to transmit the amounts of power which will be required upon the proposed system, but they nevertheless form an important nucleus of the ultimate superpower system in that they will become the distribution lines over which the power produced will be transmitted from the load centers to its ultimate point of utilization, and this existing network of transmission lines instead of being scrapped and discarded, will, on the other hand, have to be largely extended in order to dispose of the energy produced by the superpower system.

Use of By-Product Coal Plants

The high prices received for coal since 1917 have been instrumental in making many believe that not only could a greater utilization be obtained from coal through some processing method, but that the process fuel obtained, when used in large power plants, could be produced at a cost that would in turn lower the production cost for power.

Mr. O. P. Hood of the Bureau of Mines made a study of this problem for the Survey and he came to the conclusion that in general, the use of by-product fuel plants under the conditions existing would not result in lower cost of power production when such plants were used as an auxiliary to the power plants. For special locations where high prices could be received for the gas produced, it is possible that some saving might result. The studies made by Mr. Hood were confined to power plants designed to burn bituminous fuel, located within the limits of the superpower zone itself, and no study was made of the application of by-product coal plants serving base load steam-electric plants located in the bituminous coal fields, for the reason that such stations were found to be impracticable at the present time.

Coal Delivery Routes

The location of base load steam-electric plants with reference to coal delivery routes is of the utmost importance. Insurance to continuity of service from a reliable coal supply is obtained by locating base load steam-electric plants at points where coal may be received from the mines over more than one route. In addition, the location of the base load steam-electric stations with reference to the coal routes effects the total production cost in that by a judicious selection of the location, the delivery cost for coal may be reduced.

For the proposed superpower system as of 1925 and 1930, while the freight rates used were taken at a higher value than those actually paid in 1919, the unit cost of coal delivered to the superpower plants was lower than the actual cost of coal delivered to the steam-electric stations in operation during 1919, and this reduction in unit cost is entirely due to the location of the base load steam-electric stations at strategical points in respect to the cost of coal.

Conclusion

Steam-electric stations, while of prime importance in the superpower zone, due to the fact that at least 80 per cent of all the energy produced must be generated therein, cannot of themselves produce the results prophesied in the Superpower Report. Hydroelectric developments are of great importance because through their use the base load steam-electric plants can be made to function so as to produce cheap energy. Finally, without the interconnecting transmission system over which loads may be transferred, thus taking advantage of diversity capacity, diversity economy and joint reserve, the superpower plan as presented would be impossible. The subjects of hydroelectric plants, transmission system and the superpower system as a whole will be treated by Mr. Imlay in the paper following.

The construction of the Prague-Nuremberg telephone line has been completed and it will now be possible for Prague to communicate with Paris by telephone via the already existing Nuremberg-Zurich-Stuttgart-Frankfort-Paris line. Prior to completion of the Prague-Nuremberg branch, all messages sent to Prague from Zurich were transmitted by way of Berlin. Test messages are now being conducted between Prague and Zurich and will be followed by opening of the entire line—a matter of special importance to Czechoslovakia.

The Superpower System—II

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Review of the Subject.—*On account of diminishing fuel supply the development of our hydroelectric resources is imperative. It is probably the most fruitful field for conservation of natural resources open to the present generation. Under modern conditions there is an increasing demand for a continuous supply of energy in all channels of industry. Development of our hydroelectric resources probably requires more careful analysis than any other engineering problem confronting us.*

There are three types of hydroelectric developments, (1) plants depending on uniform stream flow, (2) plants on rivers having variable stream flow, and (3) plants on streams "regulated" by storage reservoirs. The Niagara and St. Lawrence belong to the first class and are suitable for development of base load plants. The Susquehanna belongs to the second class and should be developed for "run of river" power. The third class includes the Connecticut, Hudson, Delaware and Potomac which should be developed with storage for carrying peak loads.

The principal transmission lines in the superpower zone should operate at 220 kv. Where the lines are long, intermediate stations with "phase modifying" equipment may be desirable. The distribution lines should operate at 110 kv. Successful operation depends on ability to localize trouble as it is now done on large utility systems. Adequate protective devices and selective schemes for disconnecting defective circuits are essential and these are available. Voltage regulation is effected by excitation of synchronous apparatus in consumer's plants supplemented by synchronous equipment at load centers.

The benefits from an interconnected system are, (1) it permits base load plants to be operated at high capacity factor, (2) it permits development of water power on rivers that otherwise would not justify it, (3) it saves fuel by permitting the less efficient plants to be shut down at times of light load and (4) it improves the service.

Ninety-three per cent of the energy in the superpower zone is generated at 25 and 60 cycles and is almost equally divided between them. The demand for 25-cycle generating capacity is stationary while the demand for 60-cycle generating capacity is increasing rapidly. In an 80,000-kw. turbo generating and distributing plant the saving by using 60 cycles is 19 per cent of the utility investment and 16 per cent of the customer's investment. The total saving is 17.5 per cent. A common frequency is necessary for general interconnection and all signs indicate that this will be 60 cycles.

The justification of the superpower system is the saving in cost of power. By the year 1930 the investment for energy supply will be $163,000,000 less than with individual operation. The saving in coal will be 19,000,000 tons per annum. The total annual saving in fixed charges, general expense and operating expense will be $239,000,000.

A proper attitude of federal and state regulatory bodies is essential to the success of the superpower project. It should be allowed to earn a liberal income, and capital, labor and the public should share in the benefits. A superpower plan carefully worked out will be a credit to the people of this country not only as an engineering accomplishment but will show our ability to organize large things which will build up industry and at the same time prevent economic waste.

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Hydroelectric Development

DEVELOPMENT of the potential water powers of the United States is probably the most fruitful field for conservation of natural resources that is open to the present generation. Fuel supply is gradually diminishing and increasing in price, making it imperative that careful consideration be given to the development of our water resources. To the popular mind the development of power from the potential energy of water flowing in streams is the simplest kind of engineering. He has in mind the saw mill and grist mill of fifty years ago operated by a waterwheel made by a local millwright. When more water flowed than was required to operate the mill the surplus went over the dam, when less water flowed than was required to run the mill, it was shut down until rains came and the stream rose. Modern conditions have changed all this. Continuous demand for energy at constantly varying rates into all channels of human activity is a condition of modern civilization. The hydraulic engineer must see how large a portion of this demand for energy can be economically supplied from our potential water resources. There are probably no engineering problems confronting us today that include more factors and require more careful analysis than those of hydroelectric generation of energy and its transmission to centers of demand.

The question is often asked, "What are the potential water-power resources of this country?" Dr. Steinmetz estimates that the maximum possible hydroelectric power that could be produced if every river, stream and brook could be developed for every foot of its fall and the energy distributed evenly throughout the year is 230,000,000 kilowatts. The capacity of the hydroelectric stations in the United States at present is about 7,000,000 kilowatts. All we know at the present time is that the available undeveloped waterpower must lie between these two figures. The capacity that can be economically justified at any future date depends upon the demand and the cost of power at the point of demand, produced by any other source of energy. Cost of money, fuel and labor and the effect of governmental regulation are factors in determining at any particular time and place the relative and aggregate

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amounts of water power that can be economically developed.

In general we know that by far the greatest amount of economically available potential water energy is in our western states. This is due partly to the greater fall in the rivers of that country and in part to the greater cost of fuel, thus making water power relatively more valuable than in the east. At the present time the demand for energy in the west is much less than in the eastern states. In the east the potential water energy is not only much less than in the west, but fuel is cheaper. The west has maximum water-power resources and minimum power demand while the east has minimum water-power resources and maximum power demand.

In the superpower zone in 1919 the capacity of generating plants in the public utilities was 4,451,000 kilowatts, of which 450,000 kilowatts (10 per cent) was in hydroelectric plants. It is estimated that more than 1,000,000 kilowatts additional hydroelectric power can be economically developed on the Potomac, Susquehanna, Delaware, Hudson and Connecticut rivers within the next ten years, and at a later period depending on economic conditions, the generating capacity on these rivers may be increased by still another 1,000,000 kilowatts. There are three principal reasons why these hydroelectric developments have not been made in the past. *First*, on account of the high investment cost; hydroelectric developments costing approximately twice as much per kilowatt as steam plants. Frequently it has been found necessary to install a steam plant as reserve over low water periods, resulting in higher cost per kilowatt-hour generated, on account of the difficulty in raising the large amount of money necessary to regulate the stream flow and to install the hydroelectric plant. *Second*, because hydroelectric plants are generally at a distance from the point where the energy is used, thus requiring long-distance transmission lines. People have not always been satisfied that reliable service could be given under these conditions, and service over some of the lines built in the early days gave ground for this opinion. *Third*, and principally, on account of existing centers of demand not being able to absorb the hydroelectric energy at the times and in the varying rates at which it could be generated.

Types of Hydroelectric Development

There are three principal types of hydroelectric developments which may depend either upon the character of the stream flow or upon the demand to be supplied. *First*, plants depending on uniform stream flow for supply of base load service. Uniform stream flow may exist naturally as in the Niagara and St. Lawrence Rivers or it may be produced artificially by means of storage. *Second*, plants on rivers having variable flow where seasonal storage is impracticable. Such "run of river" plants generally have daily storage capacity sufficient to operate for several hours each day even during periods of low water. During periods of low water these plants are operated on peak load and during the remainder of the year on base load. *Third*, plants on rivers having naturally variable stream flow but provided with seasonal storage at the headwaters and daily storage at the plants, which adapt them to carry peak loads. Such plants may have two or three times the generating capacity that would be required if the plants were used to supply base load. After the storage reservoirs, dam and intake works are built, additional turbine and generator capacity can be installed for less than half the cost of the same capacity in a steam plant. When we remember that in the superpower zone to supply the last 50 per cent of the demand requires but 14 per cent of the total kw-hr. it often appears that a so-called "overdeveloped" hydroelectric plant is the cheapest source of peak power. Furthermore this arrangement permits the use of the very highest efficiency steam plants to supply the base load.

Classification of Superpower Zone Rivers as to Most Suitable Type of Development

A completely regulated stream can be developed at least cost to carry base load. Energy required to carry the peak of the load always costs more per kw-hr. than the energy required to supply the base load. Plants on a fully regulated stream can nearly always be extended to carry the peak load at less cost than it can be carried on a stream plant. On the other hand where a stream is naturally regulated (as the St. Lawrence) plants operated therefrom can most economically be used to supply base load, as otherwise for the greater part of each day water will be running to waste and generating equipment standing idle. The Niagara and St. Lawrence are examples of rivers with natural regulation and should be used to supply base load energy. The Susquehanna is not reasonably susceptible of regulation and must be developed for "run of river" power, supplying base load during high water and peak load in periods of low water. The Connecticut, Hudson, Delaware and Potomac should be developed with storage for peak load service.

The Potomac is a very good example of a stream which has a very variable flow and which should be developed with a large amount of storage for supply of peak loads. Its drainage area is 11,500 square miles. The average run-off is about 12,000 cu. ft. per sec. The fall from Point of Rocks, Maryland, to tidewater is 204 feet, practically all of which can be developed. There are good reservoir sites on the Great Cacapon. The Shenandoah, South Branch, and at Great Falls, the main power house site, with total capacity for storage of about 65 billion cu. ft. of water. From this can be developed about 150,000 kilowatts for base load supply, and two or three times this amount when the peak load in the southern district justifies it.

The production cost of hydro-electric energy derived from the waters of the Potomac is as low as if not lower than that from any other river in the superpower zone.

There is another advantage in development of the Potomac River with storage that may be of great value in a few years. There are three locations near the bituminous coal fields where it will probably at some time become practicable to generate steam-electric energy for transmission into the superpower zone. The best one of these sites is on the Potomac River a few miles from Cumberland, Md. just below the point where the south branch empties into the main river. A 300,000-kilowatt steam-electric plant will require about 1,700,000 tons of coal annually and 1200 cu. ft. per sec. of cooling water. This location is about twenty five miles from the famous Georges' Creek coal field where there are still large veins of coal practically untouched which is of excellent quality. With about twenty billion cu. ft. of water storage on the south branch there will be available an ample supply of uncontaminated condensing water. When the time arrives in which the energy from both the hydroelectric and the steam plants can be absorbed in the southern district, the steam plant will be used to supply base load, and the hydroelectric peak load. This combination will produce the cheapest energy available anywhere in the superpower zone.

In addition to the water power available on the main streams mentioned above there are a great many sites in the superpower zone where small water powers mostly without storage, can be developed to advantage as soon as a market can be found for the kind of service which they can give. When the superpower transmission and interconnecting systems cover the country many of these small water powers can be readily connected to the general system which will absorb all the power these plants can generate. Every kilowatt-hour generated by these hydroelectric plants means about 2 pounds of coal saved.

Transmission and Distribution Systems

The superpower system of transmission and interconnection should be limited to two voltages. The transmission circuits, operated probably at 220,000 volts, will be used for bringing large amounts of energy into the zone from distant sources over lines on which a minimum amount of switching will be required. Where the circuits are very long it may be found desirable to introduce one or more intermediate stations with synchronous phases modifying equipment. Where conditions of service will permit, a certain amount of drop in voltage between the generating stations and points of delivery is permissible in order to reduce the cost of regulating equipment.

Tie lines will be operated at a much lower voltage, probably 110,000, and the voltage will be maintained constant at all load centers. The load on the tie lines will vary greatly and as much of the switching as possible will be done on these or the still lower voltage distribution circuits of the utility companies. There will doubtless develop difference of opinion as to the proper voltage for these tie lines, and that which will finally be adopted will necessarily be the result of study of concrete examples of proposed lines.

The economical design of tie lines for the superpower system would present no difficulty if it could be ascertained just what they will be called upon to do. For example, a tie line between Newark and Philadelphia with capacity to permit of exchange of 50,000 kilowatts might be ample at first to balance the loads, and to insure reserve capacity at both ends of the lines; but in a short time, due to load growth and dismantling of old inefficient plants, this capacity would be entirely inadequate. If experience is a guide for us, we may note that few, if any, regret having adopted too high a voltage for transmission of power, but many have regretted adopting too low a voltage, as is attested by the fact that they are now raising it.

Whatever voltage may be adopted for these tie lines, it is obvious that it should be standard throughout the system. This will assist the manufacturer of transformers and standardize line construction. Transformers can be shifted from one place to another as loads increase or conditions change.

There are four principal reasons why 110,000 volts should be adopted for tie lines in the superpower zone. (1) Experience has shown that lines operated at this voltage can be tapped with safety and that switching apparatus for this voltage has been fully developed. (2) It is better to start with a voltage somewhat higher than necessary than to start too low, as the demand on the line will be growing and thus increasingly tend to justify the higher voltage. (3) 110,000 volts will be none too high for some of the principal tie lines. (4) It is a reasonable compromise between heavy and light service such as that required of the Boston-Northampton line compared with the Providence-New Haven line.

Operation and Regulation of Interconnected System

The successful operation of the superpower system depends on the ability to handle trouble on any part of the system without interfering with the rest of the service. On any large utility system there is almost continuous trouble involving interruption to some of the connected load. This trouble is generally taken care of without the knowledge of customers not involved in it. Unless the trouble involves considerable load even attendants at the generating plants are not aware of it. Adequate protective devices for automatically disconnecting defective circuits or apparatus, and facilities for supply of service in more than one way, with ample reserve equipment, are the secrets of good service. Service from the superpower system is the same problem on a larger scale as that which confronts

every public utility. Very effective selective schemes for disconnecting defective circuits have been worked out, but the problem becomes increasingly difficult as the size of the circuit breakers increase. However, circuit breakers have been designed which with properly proportioned current limiting reactors on the system are adequate to take care of the superpower system as it has been planned.

Voltage regulation on the interconnected system will be effected by excitation of the synchronous apparatus assisted in many cases by synchronous condensers, otherwise known as "phase modifiers," located at the ends of the tie lines. On some of the longer tie lines of small capacity, induction regulators will be used to raise and lower the voltage.

Effect of Interconnection of Load Centers

There are four principal benefits to be derived from the interconnected system:

(1) It permits base load steam and hydroelectric stations to be operated at high capacity factor and the less efficient steam stations and hydroelectric stations using stored water to carry the peak loads. There will be the widest possible selection of the most economical sources of energy at all times of the day and at all seasons of the year. For example, in operation of hydroelectric plants the aim will be that no water shall go over the dam, in operation of steam plants that the most efficient units shall be started first and shut down last. In other words, there will be opportunity to take advantage of diversity economy.

(2) It permits the development of hydroelectric power on rivers that otherwise would not justify development. Furthermore, it permits the "over-development" of streams favorably situated for carrying peak loads. Under present conditions of independent operation development of the Potomac River to the extent of 200,000 kilowatts would not be justified as the demand in Washington of 67,000 kilowatts, or even in Washington and Baltimore together of 199,000 kilowatts, would not be sufficient to absorb 200,000 kilowatts of twelve-hour power. But if the entire southern district consisting of Washington, Baltimore, Philadelphia and Harrisburg were interconnected with its demand of of 660,000 kilowatts, the Potomac development for peak load service could be easily absorbed. As the load in the southern district increases additional generating capacity can be installed in the power houses to carry the peak load. The cost of this equipment per kilowatt is less than for equal capacity in steam plant, the depreciation is less and the operating cost much less. The amount of stored water required to carry the extreme peak is almost negligible as 30 per cent of the demand measured from the top of the annual peak includes less than 3½ per cent of the kilowatt-hours.

(3) Interconnection is a large factor in saving of coal, transportation and labor. There will be no reason for operation of the less efficient steam stations after the peak load for the day is over. There will be no steam generating apparatus whatever operating in the small towns after midnight, or on Saturday afternoons, Sunday and holidays. This energy will be supplied from large highly efficient units in the base load steam plants or from the hydroelectric plants that are not adapted to peak load service.

(4) Interconnection will improve service. The effect of the superpower plan of interconnection by tie lines is to place a large part of its resources at the service of each community. This does not mean that the resources of the Potomac River are available for service to Lowell, Mass., but in case of trouble in Washington, the resources of the Potomac, its own local steam plants, the steam plants in Baltimore and the hydroelectric resources of the Susquehanna are available to draw from. With proper design of these interconnections service will be insured as it never has been in the past.

Frequency

There are two principal frequencies in use in the superpower zone which together comprise 93 per cent of the energy generated. The larger part of the remaining 7 per cent is energy generated as direct current. The following is a statement of the demand and energy output of the public utilities at different frequencies in 1919:

	25 Cycles	60 Cycles	D-C. and Other Frequencies
Demand ....Kw.	1,344,000	1,444,000	266,000
Energy Output Kw-hr.	4,833,000,000	4,767,000,000	700,000,000

In general 25 cycles is used in the large cities and 60 cycles is used for nearly all purposes in the smaller cities and towns. Leaving out of consideration cost of equipment, 25 cycles is best for (1) operation of alternating-current railways, (2) direct-connected low-speed motors, (3) for large capacity electric furnaces and (4) for transmission over very long lines. Sixty cycles is best for (1) incandescent lighting and (2) for general industrial motor service. Either frequency is equally serviceable for (1) railway or electrolytic work where alternating is changed to direct current, for (2) electric furnace work up to about 5000 kilowatts and (3) transmissions of moderate length.

Four years ago the technical history of the frequencies was given before the Institute by Mr. Lamme. In that story it was shown why the start was made at 133 cycles and how the pendulum gradually swung to 25 and even 15 cycles and is now on its way back with prospect of settling at 60 cycles. These changes were all made in an attempt to find a universal frequency by which a single system could supply the demands of lighting, industrial power and traction. The manufacturer of electrical apparatus had continually before him the limitations in design, while the purchaser had to look

to the cost and to the quality of the service. The result is that we now have in the superpower zone two frequencies each supplying about 47 per cent of the service.

In order to carry out the superpower plan to its logical conclusion and interconnect all of the load centers in the zone, a common frequency is necessary. The frequency which will predominate will be determined by process of evolution and in accordance with the law of the survival of the fittest. The desires or prejudices of individuals will count for very little in the final result. Other things being equal that which will come nearest to serving all the requirements at least cost is the frequency that will be adopted. The following estimate shows approximately the difference in investment for the two frequencies in the electrical equipment of a modern steam plant and for customers' use, in a city of about 250,000 inhabitants:

	25 Cycles	60 Cycles	Saving
Utility Investment....	$3,614,000	$2,914,000	$700,000
Customers' Investment	4,330,000	3,642,000	688,000
Total Investment....	$7,944.000	$6,556,000	$1,388,000

By using 60 cycles the saving to the public utility will be 19 per cent, to customers 16 per cent and the total saving will be 17.5 per cent or $1,388,000.

A study of the trend of sales of generating equipment shows that 25-cycle is increasing very slightly if at all and that the sale of 60-cycle apparatus is increasing very rapidly. Such a verdict as this cannot be ignored and we believe that every one should concur with this decision. Ten years from now the electric generating equipment in the superpower zone will have more than doubled in capacity if past growth is any guide. If all new installations are made at 60 cycles by 1932 the 25-cycle service will have become comparatively small and that which remains can gradually be changed to 60 cycles as equipment has to be replaced. It will not be necessary to scrap all of the 25-cycle equipment. Some synchronous converters can be rebuilt. Twenty-five cycle transformers can be operated at 60 cycles for incandescent lighting and for other purposes at increased capacity. Frequency-changers may be used on power circuits during the transition period. In most cases the synchronous motors on the frequency-changers should not be considered as part of the cost of making the change as these motors will be needed in any case as "phase modifiers" to regulate the voltage on the interconnected system. In Baltimore there is now a comparatively large capacity in frequency-changers which are used to supply the lighting and domestic load at 60 cycles. When future increases in generating capacity are made at 60 cycles these machines can be reversed and used to supply 25-cycle energy as the more inefficient generating units of that frequency are abandoned. In this way the entire zone may gradually be changed into a 60-cycle system.

Savings and Earning Power of Superpower System

While one of the prime objects of the superpower system is conservation of natural resources in saving coal by using it more efficiently and by using water power, its justification to the present generation is the saving in cost of power. If it costs less to burn coal than it does to save it by using water power, coal will be burned irrespective of conditions two hundred years from now. If power can be generated more cheaply by burning raw coal than it can be generated by using process fuel, taking into account credits for the by-products, raw coal will be used. Fortunately conditions are such at the present time that large savings can be made by developing water powers which will result in conserving much coal. As fuel increases in cost, water resources will be further developed, perhaps far beyond what we now realize as possible.

Savings effected by the superpower plan will be more fully realized as time goes on. By the year 1930 it is estimated that the investment for energy supply will be about $163,000,000 less than with individual operation. Saving in coal will be 19,000,000 tons per annum worth $96,000,000. Saving in operating expense will be $59,000,000 and the saving in fixed charges and general expenses will be $123,000,000 and the total saving will be about $278,000,000 per annum. If we deduct from this $39,000,000 the amount necessary to amortize the abandoned plants in eight years, the net saving in 1930 will be $239,000,000.

Investors in existing plants should remember that the plan provides for the amortization of $182,000,000, the estimated cost of the inefficient plants to be abandoned. This will leave only the more efficient plants in service, thereby increasing the earning capacity of the remainder of their investment. The earning capacity of hydroelectric plants will also be increased as interconnection will provide a market for all the energy they can produce.

General Conclusions

A proper attitude of the regulatory bodies of the federal and state governments towards the superpower project is essential to its success. Restrictions on the earnings of utilities as imposed by many public service commissions have removed incentive to economical production of power. If a utility is well planned, financed and managed and earns more than the percentage allowed, its rates for service will be reduced. If it is not well financed and well managed and fails to earn the percentage allowed, it is permitted to increase its rates. Thus no incentive is given to economy or good management, and if these are wanting the customer only is the loser. Capital, labor and the customer should all share in the benefits of skillful and economical management of industry.

The effect of a liberal attitude by regulatory bodies will enable an enterprise to secure money on the best possible terms. If the investor knows that the utility

will be allowed to earn a good return he will accept a lower rate of interest than if he knows he must take chances on the industry being a successful one. If the industry is allowed to earn a liberal income and lay up a reasonable surplus it can afford to treat labor liberally. Finally the purchaser stands a better show of cheap power when the enterprise is wisely financed and skillfully managed and operated by a well paid and loyal staff.

The justification for the superpower system is the saving that can be effected by it. The saving will consist in a better use of capital, lower cost of fuel, lower operating and maintenance costs and lower fixed charges and general expense per unit of output. Cheaper power will assist us in competition in the markets of the world. Our factories *now* have greater capacity than is needed to supply our own national requirements and we hope to expand them indefinitely. We must look to foreign markets to keep our factories busy, and there we must compete with cheap labor and raw materials. Every step in the manufacture and marketing of goods must employ power to the utmost extent in place of expensive labor which has come to stay. And that power must be produced and sold at the least possible cost if we are to secure and maintain the position we ought to have in the world's markets.

A superpower plan carefully worked out in the Atlantic Seaboard states, and throughout this entire country and Canada, will not only be something on which we can look with satisfaction as an engineering project, but it will be a monument to our ability to organize men and corporations with diverse interests and aspirations into a project which will result in the greatest good to the greatest number.

The Electric Hammer.

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Review of the Subject.—*The power hammer has been in use for a long time and there are now on the market many types of power-operated hammers which may be roughly classed according to the nature of the power as follows:*

Pneumatic, steam, motor and pulley; cam or crank, and electro-pneumatic drives. The pneumatic drive includes all riveting hammers; the steam drive includes practically all forge hammers, some drop hammers, pile drivers and steam drills; the motor and pulley drive class, includes the greater part of drop hammers; the electro-pnuematic drive includes only small forge hammers. The pneumatic hammer, due to its lightness, holds the field of hand-operated riveting hammers and it is hardly possible that any other means will ever surpass air for driving hand-operated riveting hammers; the steam hammer holds its own in very large forging and drop hammers and it is doubtful whether any other kind of hammer can remove it from that place. The field for very large forging or drop hammers is however rather limited; they are used only in very large plants in which all sorts of power prevail.

There is an immense field, however, for medium and small forging and drop hammers which are used to produce all the small automobile and other similar parts as well as name plates, jewelry apparel, etc. It is this field which the electric hammer is supposed to cover. The present methods of driving these hammers are cumbersome, complicated, costly and very unsafe for the workman.

The electric hammer has been studied and developed by the writer to a point where it seems to show superiority to the present used hammers, in simplicity, safety, running expenses, cost of installation, cost of upkeep and in many cases in the original cost.

The development shown herein is of the induction motor type. Instead of the usual arrangement of concentric armature and field, the slots are punched on long strips of iron in a straight line which makes the field and armature parallel. The armature and field still face each other but every part of the aramture is not always active under th: influence of the field as is the case in the ordinary motor. In other words in a straight-line motor the armature or runner is continuously entering the field of action at one end and leaving it at the opposite end. This constitutes the main difference between the straight-line and the rotary motor. The rotating fields of an induction motor are here replaced by magnetic fields moving in a straight line. The principal elements of this straight-line induction motor hammer are shown in Fig. 3. The actual hammer as finally constructed is shown in Fig. 5 (back view) and Fig. 6 (front view.)

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Definitions

An electric hammer as described in this paper constitutes a hammer in which the reciprocating part is moved solely by the direct action of the electromagnetic forces without interposition of any other mechanism, such as belts, gears, compressed air, etc.

The electrical portion of the reciprocating part, which is analogous to the rotor of a motor, will be called the runner while the die holder which is attached to the runner is called the ram.

Electric hammers may be divided into four classes: Direct-current, semisynchronous induction, nonsynchronous induction and purely synchronous. A direct-current hammer consists of two symmetrical straight armatures mounted facing each other between which

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moves the field carrying with it the brushes; it may also be made with two stationary fields and one moving aramature. A semisynchronous induction hammer is made by setting two polyphase straight-line stators

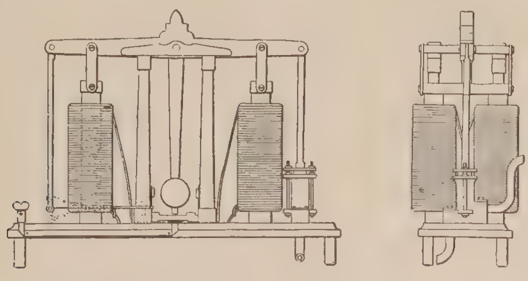

Fig. 1—First Patent on Reciprocating Motor
Issued in 1852.

facing each other with a squirrel-cage runner moving between them; the reversal of the current is made by a switch rigidly connected to the generator shaft so that the phases are reversed at zero potential and at predetermined intervals. A two-phase hammer fed with two phases of different frequency in which the reversal comes at the nodes of the two frequencies may also be classed as a semisynchronous hammer.

A nonsynchronous induction hammer is made exactly as a semisynchronous induction one with the exception that the reversing of the phases at each end of the stroke is done by the runner itself. A purely synchronous hammer may be defined as a hammer which gives one stroke per cycle. This type of hammer may be made of the simple plunger type or of the excited plunger type.

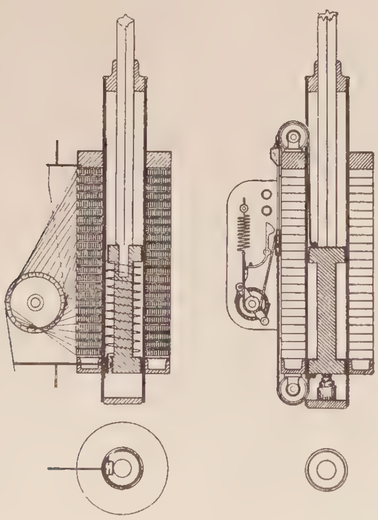

Fig. 2—A Well Developed Idea on Straight-Line Motors
Patented in 1885.

Historical

The writer invented the electric hammer early in 1915, when still in school. After coming out of school, the war was in full swing and it was thought inadvisable to start developments of any kind. The studies were made independently but the following historical treatment will show that it was not an invention but a reinvention.

The subject of the reciprocating motor in general is practically as old as that of rotary motors; this fact is shown by the records in the Patent Office from which it is seen that the earliest attempts to make electric motors were mainly along the lines of imitating the reciprocating steam engine and the first patent for a reciprocating motor to be applied to a pump was issued in 1852; a picture of this device is reproduced in Fig. 1. In 1870, there were some attempts made to operate sewing machines with reciprocating electric motors. In 1880 appear two patents on a solenoid rock drill. In 1885, the Van Depoele patent appears. This patent is reproduced in Fig. 2 from which it may be seen that engineering was, at that time, being applied to this line of inventions, for it is quite a well developed machine which may easily be made practical by properly proportioning it. It is a d-c. machine in which the armature is stationary and the field moves. An important feature of this machine is that the plunger is excited while machines of previous dates were made with a nonexcited plunger, that is, they were mere electromagnets and with this machine we pass from electromagnets to straight-line motors. The idea of plunger reciprocating motors and straight-line d-c. motors prevails until the present time and it would be useless to recount here the innumberable patents that have been issued on the subject. It may be said, however, that the idea remains unchanged and the only thing that changes is the inventor.

In August, 1901, a patent was issued to R. D. Mershon on a straight-line nonsynchronous polyphase induction motor for a rock drill. He mentions in his specifications that prior to that time polyphase rectilinear motors have been proposed in which the reversing of the fields was done by a switch connected to the generator; that system he condemns because the vibratory period of the motor would have to be of certain value in order to be in synchronism with the generator, and consequently it would not start from rest unless those conditions were fulfilled. His system has a reversing switch operated by the moving part of the motor and consequently makes the latter completely independent of the generator. As far as the writer can find, this is the first record of a practical polyphase rectilinear motor.

In 1905, a patent was issued to P. Centener. This machine is based on an entirely new principle. In this machine, each stator is fed with two separate sources of alternating current of different frequencies and in this way the motion of the field is reversed at the beats occurring in the two frequencies so that the moving part would reverse its motion without the necessity of reversing the currents by means of contactors or switches. While this machine is built on different principles from those criticised by Mershon,

its faults are the same, namely: It has a constant period and it requires special generators to operate it.

In 1909, a patent was issued to T. F. Bailey in which the same invention as is shown in Mershon's patent was described with the exception that the application is made directly to a forge hammer instead of to rock drills.

The success of these inventions in rectilinear motors is apparent from the fact that none of them are at the present time on the market. Of the semisynchronous hammers, the only successful machine that the writer knows of is that made by Professor Leo Schüler of Berlin, Germany, described in U. S. Patent No. 1115251. He actually made a small chipping plunger hammer that would work successfully. From his account in the *Elektrotechnische Zeitschrift*, it is hard to understand why the machine has not been put on the market unless it is for the reason that it requires special generators for the supply of power. It is not known to the writer whether or not there have been built any polyphase rectilinear motors operating on the principle brought out by Mershon, that is, in which the reversing is done by the motor itself. Mr. Charles Fair, who was employed by the G. E. Co. at the time this work was started, said that he had seen a model of the d-c. plunger-type hammers which he described as not being "lively" enough for forging purposes. The machine, as he described it, was made up of a series of solenoids in which moved a plunger. The plunger was first attracted by one solenoid, the current was then switched to the next one and the plunger moved with the current. Irrespective of whether this machine was "lively" or not it is easy to see what difficulties would be encountered in shifting the current from one solenoid to another at the time of maximum inductance. In other words, it may be said that this machine was a very badly designed direct-current motor.

The reasons why the electric hammer was not developed appear to be the following: In the early days of electrical development the demand for hammers was rather small; rotary motors could be used for many more applications than the special uses for which the straight-line motors were proposed; hence it became much more remunerative to develop rotary motors than to develop straight-line ones. Once a rotary motor was available in its perfect form it became much easier simply to take a standard motor and apply it to the particular use for which it was needed than it would have been to develop a new special motor.

It may be said further that in the early stage of electrical development, the total demand for motors was very small and of this total demand the percentage which required an ordinary standard motor was far greater than that which required a special straight-line motor, so that it was altogether out of question for any manufacturer to undertake the development of as many special motors as there were special cases to be taken care of. At the present stage of electrical industries, the conditions are precisely reversed in that there are now many special cases which require a much larger number of motors than was required for the total electrical industry in the earlier days of the art and certainly anybody who is acquainted with the industry will agree that many manufacturing enterprises are now existing, and in fact prospering in the manufacture of only one or two special appliances. It is for this reason that it is felt justifiable to state that the application of standard rotary motors to special cases has gone beyond its limits.

The above is, it is hoped, the answer to the many questions that are continually being asked as to why it is that nobody else has ever tried to develop an electric hammer before this if it is as simple as it looks. It is also an explanation of the arguments which led to the undertaking of this development.

As a matter of fact, it is felt that the development of a new special machine will always be justified as long as the demand for it is large enough to build up a reasonable amount of business and its qualities are such as to guarantee its preference to existing systems.

Preliminary Studies of the Electric Hammer

When the study of the electric hammer was undertaken, the subject was so new from an engineering view point that a preliminary study was required in order to decide which system of those mentioned would be the best to use, also to determine fully the advantages of an electric hammer over those hammers which it was to replace.

In studying the problem in general, it is found that an electric hammer is essentially an apparatus which is continually starting and stopping; electrically, therefore the apparatus best fitted for this purpose would be an apparatus which gives the best efficiency during the starting period. A d-c. series motor is evidently the best apparatus to use for such purposes. On the other hand, a power hammer must be so constructed as to withstand shocks without limit either in number or in size and it was doubtful whether any commutating apparatus would be capable of withstanding such rough usage as that even though the armature and commutator may be made the stationary part and the field allowed to move. The problem therefore, resolves itself into three branches; one consists of the study of the properties of the electric hammer to predetermine its advantages over the hammers which it shall replace; the second consists of a study of its mechanical stability and durability under repeated and violent shocks; and the third is a study of the electrical properties of the machine as affecting an apparatus which is continually starting and stopping.

The problem of determining the advantages of an electric hammer over a board hammer had to be resolved from fundamental considerations rather than from existing facts because there were no facts available. The main points of merit of the electric hammer were the following:

In cases where it replaces board hammers, it consumes no power while not working, there are no moving parts while it is not operating, it is neater in appearance, it occupies a minimum of floor as well as overhead space. There are no parts to wear out, outside of the runner, and the contactors (which in the final design will be made so easy to replace that it is expected will give no more difficulties than an ordinary board hammer). It is very easy to move it from place to place. The most prominent feature of an electric "board" hammer is its great variety of the size of blow that it can give, ranging from zero to four or five times as large a blow as it could give by merely falling under the action of gravity.

When the electric hammer is made to replace a steam hammer its advantages are as follows: It is a well-known fact that a steam hammer is the most accomplished waster of energy ever made by the human hand, considering all condensation on the lines, which are sometimes of great length, all the steam used to keep it warm while not in operation, and the fact that sometimes a special boiler plant must be installed to operate a steam hammer. All these losses are eliminated with an electric hammer; there can be an electric hammer wherever there is an alternating-current supply, it can be moved from place to place without much difficulty; since it can be tied to any supply system, the small manufacturer can have it, in other words anybody may have a power hammer. These qualities are what could be foreseen before any test was made or even before any hammer was ever designed.

Mechanical Stability and Durability of an Electric Hammer

Here again it was a case of predetermining these qualities from facts which were more or less self evident, because no actual apparatus had ever been built. The facts which were very apparent were the following: Compared with the board drop hammer it may be said that the runner of the electric hammer replaces the board of the board hammer, hence the electric hammer has nothing to get out of order except its "board;" against the elimination of all those parts must be set the introduction of at least two pairs of contactors (in case the third one is introduced, electrically it is possible for only two to work since two of the three are in series and either of these two must open the circuit). Also the question came up as to whether the runner of the electric hammer would withstand the severe shocks to which it must be subjected. This question may be considered from two standpoints, first if it is made of laminated steel with copper bars for the squirrel cage, the construction is apparently weak but on the other hand, it has that elasticity which absorbs the shocks much better than any solid construction can absorb them and prevents breakages.

A laminated runner is a rather costly construction but it is believed that it would last longer than a solid one and certainly much longer than boards last in ordinary board hammers. The other alternative was to make the runner of solid steel which would, by reason of its simplicity, cost so little that the replacement of it would not be at all expensive nor would it be any more difficult to renew a solid steel runner in an electric hammer than it would be to renew a board in a board hammer.

Compared with the steam hammer, it may be said that the troubles given by the steam hammer by the breaking of the piston rods on account of the crystalization which occurs where the rod connects to the ram of the hammer might be eliminated to a great extent by a laminated construction which is perfectly possible with the electric hammer, but I do not think it would be feasible in case of a piston rod which has to fit steam tight in the cylinder head (it must be remembered that outside of the ways which guide the runner in a vertical direction, it may be said that the latter hangs almost free in the air). In short, it was thought that the worst expectation that we could have was that we might have as much breakage from an electric hammer as from a steam hammer and certainly all the rest of the conveniences obtained by an electric hammer were thought to be enough to justify the change.

Field of Application of the Electric Hammer

If we consider the replacement of all steam hammers, board hammers, pile drivers and all like apparatus, the field is certainly sufficient to justify the development and marketing of such an apparatus.

The Electrical Problem

From the electrical standpoint and from the long study previously made on d-c. motors (especially the series motors), it appeared always preferable, ever since the problem was undertaken, to build a direct-current series machine; therefore proceeding on this belief, a direct-current reciprocating motor was designed and its main characteristics calculated. The runner of this machine was to be the field and was to be made of solid steel in which there were slots for the distributed field windings. The field coils were to be retained in the slots by nonmagnetic materials such as brass or bronze, and the brushes were to be carried by this moving part. The armature was to consist of two straight-line armatures, one on each side of the field, each having its own commutator so that the two might be connected either in series or in parallel with each other. (The double armature was of course necessary to balance the electromagnetic forces as well as to utilize the field metal to its fullest extent). The electromagnetic properties of this machine were found to be very excellent; the starting current was rather small and the torque per watt very large; it can be designed for very low speeds. In general, it showed the superiority of d-c. to a-c. in case of motors which have to start and stop continually under heavy load. The

electromagnetic force per pound of the active metal of the runner was very high as compared to that of the induction motor. In power hammers, and especially in the so called drop hammers where the ram must be heavy enough to hold the die, it is very important that the electromagnetic force per pound of active metal be as large as possible so that most of the metal constituting the total weight of the moving part may be placed on the ram. In electric hammers, this point is of even greater importance since the power may be applied downward and the total weight of the moving part must be decreased very much to obtain the proper rating.

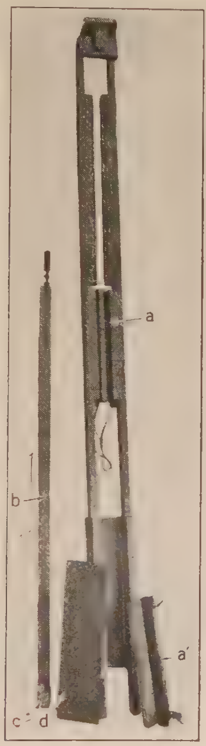

Fig. 3—First Experimental Electric Hammer

a—one of the stators mounted on the wooden frame, a'—the other stator dismounted, b—the armature or runner (a piece of brass 1/8 in. by 2½ in.) removed, c—the ram, d—a guarding plate making a part of the framework.

In spite of the preference which the writer had for the direct-current machine, it was repeatedly pointed out that it would not withstand the shocks of a hammer and it was finally recommended that the polyphase induction type be looked into before definite plans were made for building any hammers at all.

Under these suggestions, a very small model of polyphase straight-line motor, in which the moving part was made of a piece of brass ⅛ in. thick by 2½ in. wide, was built and tested. This hammer was equipped with a heavy piece of cast iron on the bottom end and also with an automatic reversing switch so that when power was applied it would reciprocate up and down like an ordinary hammer. An illustration of this crude model is shown in Fig. 3. It should be understood that this model was not made to obtain engineering data nor was it designed to give any definite result. The object of building it was merely to show the several people interested that such a hammer would work. The model proved very satisfactorily how much simpler a polyphase hammer is than a direct-current one.

After several lengthy discussions with engineers who were well acquainted with the power hammer problems, it was concluded that it would be best to start the development by building a polyphase induction hammer.

In accordance with this decision, a hammer was designed to operate a 200-pound ram, in other words, a hammer which would be equivalent to a so-called 200-pound board hammer, this comparison of course being made in a case when the electric hammer lifts a 200-pound ram, and lets it fall by gravity; in case power is added on the downward stroke its capacity would be greatly increased as will be shown in the results of the tests. For the purpose of obtaining engineering data, the runner was made of laminated steel.

It was apparent from the character of the working cycle of this machine that the runner should be made of high resistance in order to obtain high starting torques, high power factors and at the same time draw a small starting current from the circuit. This was done by using brass bars in the squirrel cage; in addition to that, both for convenience in building it and to diminish leakage reactance, the secondary slots were made open and the bars made even with the surface of the steel laminations. Making the bars even with the surface also eliminates all that portion of the primary leakage flux which passes from one tooth to the other above the secondary conductor.

About the worst thing to contend with, at least during the discussions of this apparatus, was the so-called end effect that occurs when a conductor of the rotor passes out of the stator field into the air. This difficulty, as pointed out by Dr. Steinmetz, had been one of the main difficulties which led to the abandonment of the induction railroads. To the end-effect problem, as related to this hammer, there was at least one solution and that was to be found from the fact that the efficiencies of the present hammers are so small that it was thought almost impossible to make a straight-line motor bad enough to compare with the present hammers, in other words, one solution of the problem was not to solve it at all.

Accordingly, the hammer was built with the following dimensions: Length of stator, 39 inches, length of runner 5 feet, and width of the cores, 2½ inches, or in other words, the motor was very nearly "square." It was assembled in a box made of boards 2½ inches thick, which was provided with brackets for mounting it on the uprights of an ordinary 200-lb. board hammer. The construction was made so crude because it was still doubtful in the minds of a good many of those concerned in the development as to whether it would be successful or not. The standstill characteristics were then obtained and the most important curves are shown in Fig. 4.

It was finally mounted on the uprights and since the 5-ft. runner was too short to reach to the anvil, it was found necessary to make a wooden block high enough so that it could be operated with the given runner.

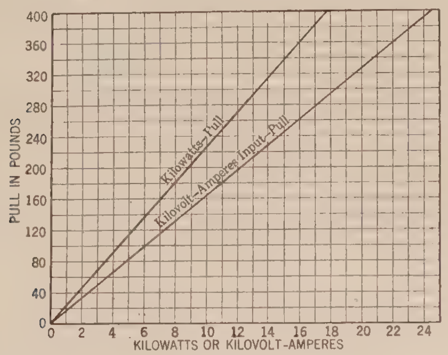

FIG. 4

Curves showing the relations between the total kilowatts input and the total pull exerted on the runner; also the relation between the total kilovolt-amperes input and the total pull exerted on the runner.

The switch mechanism consisted merely of a reversing knife switch automatically operated by the moving part and no connection was made between the switch mechanism and the treadle, so that to start the hammer it was necessary to close the main switch. Once it was closed the hammer kept on going up and down at the rate of about three strokes per second.

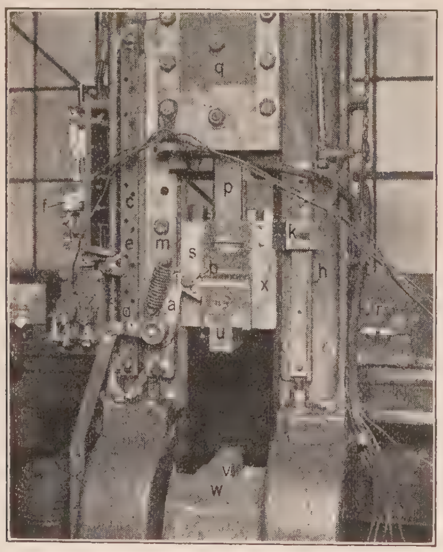

FIG. 5—EXPERIMENTAL ELECTRIC HAMMER (BACK VIEW)

Main parts: *p*—armature or runner, *q*—stator casing, *x*—ram, *u*—upper half of die, *v*—lower half of die, *w*—anvil.

Auxiliary parts: *a*—holding dog, *b*—holding block, *s*—spring which actuates both the dog *a* and the lever *c*, *e*—a lever crank, *f*—cut-out contactor operated by dog *a* through lever *c*, *r*—switch for controlling power on downward stroke.

This model, as crude as it was, was sufficient to show that the electric hammer was a success. In addition to that, we obtained starting currents, and power factor, and cleared in this way all those questions which were up to that date a stumbling block for the development; it was shown, in other words, that operating an electric hammer did not wreck the supply system, as was thought by many. No photographs were taken of this model when it was mounted, but outside of the wooden anvil, it was exactly the same as that shown in Fig. 6. Having cleared all these difficulties, it was decided to build a real model capable of performing the same functions as an ordinary 200-lb. board hammer.

In the new model, the same stators were used and the work of the new design consisted merely of designing a pair of uprights together with the proper automatic switching mechanism necessary to have the electric hammer operate analogously to the board hammer.

At this point Mr. D. C. Garroway, an engineering draftsman, began to assist me in the development of the present model.

FIG. 6—EXPERIMENTAL ELECTRIC HAMMER (FRONT VIEW)

Main parts: *Q*—motor casing in which stators are mounted, *P*—armature or runner, *X*—ram, *U*—upper half of die, *V*—lower half of die, *W*—anvil.

Auxiliary parts: *R R'*—follower rods, *f f'*—followers, *T T'*—cams, *C'*—cut-off contactor, *C*—one of reversing contactors, *A A'*—switching arms operated by *R R'*, *S S'*—switching springs, *K K'*—contactor cranks. Arm *A* moves spring *S* to one or the other side of *K* and the spring does the switching.

The cycle of operation of an ordinary drop hammer is as follows: Ordinarily, a hammer hangs up in place and when the treadle is pressed, it falls down and automatically returns up to its original position and keeps on going up and down as long as the foot is kept on the treadle. As soon as the latter is released no matter where the hammer is it continues its operation until it gets up to the upper position and hangs itself there ready for the next operation. It was necessary, therefore, that an electric hammer be capable of performing the same cycle. To do this, it is essentially necessary to have a cut-out contactor and a pair of reversing contactors. The cut-out contactor must be operated automatically by the moving part so that when the hammer hangs itself on the upper position the circuit is open. The reversing contactors are for the purpose of reversing two of the three phases at each end of the stroke. The opening and closing of con-

tactors must be done at a constant speed irrespective of the speed of the moving part of the hammer.

In addition to these three contactors, it was decided to add a fourth one for the purpose of cutting off the current on the upward stroke before it had actually reached the end of the stroke in order to save power and also avoid the necessity of reversing at full speed.

Fig. 5 shows a back view of the hammer with the ram in its upper position. At b is shown a block fastened to the ram which engages with the dog a fastened to the uprights. The dog has an elliptical hole at its fulcrum so that when the ram comes down on it, it moves downward a half inch before it gets to the bearing. On the same dog is fastened the lever d, which is connected to the treadle and also a vertical flat piece of steel c, free to move up and down a half inch with the dog a. This piece of steel operates a lever e which in turn operates the cut-out contactor f. Therefore, when the hammer comes down on dog a, it hangs itself and also cuts out the main circuit.

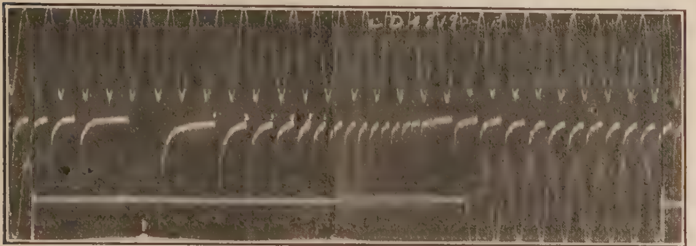

Fig. 7—Oscillogram of Electric Hammer Operating with Electric Power on Upward Part of Stroke Only, Gravity Producing the Hammer Blow.

The upper vibrator gives a smooth wave of a 40-cycle voltage which is used for measuring time. The middle vibrator shows the deflection of a direct current obtained from a dry cell which has its circuit momentarily closed at every inch of movement of the armature or runner. The time taken for the runner to move through one inch is measured by the distance between "making" points which are marked 1, 2, 3, etc. on the record of the approximate zero of the middle vibrator.

The lower vibrator shows the current of one of the three phases.

The distance between the vertical lines A and B indicates the time of one complete stroke (or cycle of operation).

Starting from the point A when the alternating current ceases the runner continues on its upward stroke until it uses up its momentum at some point about the position marked C. It then begins to fall slowly by gravity, as shown by the distance between the vertical lines of the middle vibrator, and gradually accelerates until the hammer strikes. Shortly after, the current to lift the runner comes on again for eight and a half cycles to point B where the cycle of operation starts to repeat.

The spring s has two functions, one is to keep the dog a in its upper position and in that way keep the contactor s closed, and the second function is to keep the dog a always turned to the right under the block b. The vertical motion of a and therefore that of c is always quick and consequently no additional mechanism was needed to make the opening of the contactor fast enough to eliminate burning.

Fig. 6 shows a front view of the hammer also with the ram in its upper position. The two rods R and R' carry the cams and levers to operate respectively reversing contactors C and the "cut-off" contactors C'. These rods are made long enough to be able to get the stroke of any desired length from zero to the length of the uprights. The cams that are fastened on these rods are operated by two studs T and T' fastened to the ram. The arms A and A' also connected to these rods operate the reversing contactors and the "cut-off" contactors respectively. In order to assure a constant opening and closing speed of the contactors, the opening is done through springs S and S'. All that arms A and A' have to do is to move one end of the spring S and S' on one side or on the other of the center of the contactor cranks K and K' and the opening and closing after that is performed by the springs independently of the cams or the moving part of the hammer and hence it is done always at practically the same speed, which can be adjusted by adjusting the tension of the spring and its eccentricity.

Since this hammer is provided with reversing mechanisms, it is evidently possible to apply power on the upward as well as on the downward stroke and here is where the electric hammer differs from the board hammer. In order to cut off the power in downward stroke, it is necessary to have also an ordinary knife switch in series with the circuit for the downward stroke. This switch may be seen at r in Fig. 5. By changing the position of the cam F', it is possible to regulate the length of "admission" and by changing

TABLE I.

Working Characteristics of Hammer Already Existing

Kind of Hammer	Hammer Number	Rating in Lb.	Total Time Hours	Total Strokes	Useful Strokes	Average Strokes per Hr.	Average Useful per Hr.	Max. Strokes per Hr.	Max. Useful Strokes per Hr.
Board	1	400	6	5900	5900	984	984	2060	2060
Board	2	400	4.5	7645	7645	1700	1700	2475	2475
Board	4	600	12.0	9740	9740	810	810	1400	1400
Board	5	800	6	1610	1610	170	170	315	315
Board	6	800	12.25	3646	3646	297	297	403	403
Air	8	700	2	3226	3226	1613	1613	2322	2322
Board	11	600	6	4591	4591	772	772	985	985
Board	17	1200	6	3857	3857	642	642	702	702
Board	20	1200	6.5	2327	2327	358	358	468	468
Board	22	1600	3	1173	1173	391	391	500	500
Board	24	1600	6	1542	1542	257	257	483	483
Steam	32	3500	6.5	21800	2971	3350	429	3600	795
Steam	34	2500	3.0	8120	1128	2707	376	3480	598
Steam	37	1000	6.0	9075	2107	1512	351	3000	881

the position of F, it is possible to regulate the point of reversal. The length of the stroke can be changed only by changing the position of a in Fig. 5 and that can be done only by moving the steel block m upon which a is fixed. Holes are provided on the upright and also on the steel piece c for changing the length of strokes.

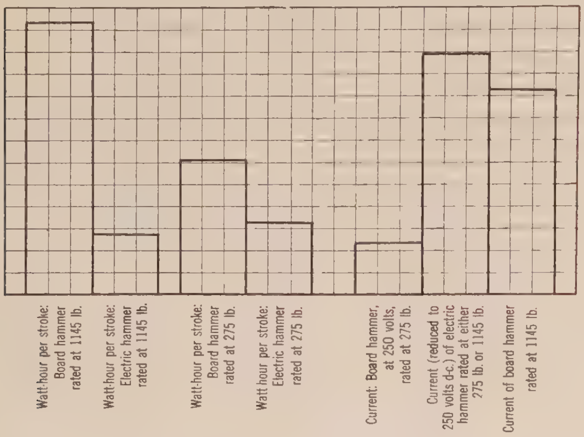

Fig. 8—Chart Giving Comparison between Electric Hammer and Board Hammer which it is to Replace

Comparison of efficiency is made in watt-hour per stroke. Current efficiency is given in amperes. The hammers are compared both at a rating of 275 lb. and at a rating of 1145 lb.

It is evident that by inserting resistances in series with the downward circuit, we may apply any amount of power ranging from zero to full value on the downward part of the stroke. Also by making the switch r a reversing switch, we may apply upward power on the downward stroke also from zero to full value. This gives a range of blows from zero to a blow given when full power is applied downwards.

Tests of the Hammer

In order to test the hammer it was necessary to obtain the speed at the time of impact, the upward and downward accelerations, current at starting and on running, energy input per stroke etc. The oscillograph method was the only method available to do all this. The hammer was therefore equipped with a sliding contact mounted on the ram and made to slide against a long piece of fiber in which there was a strip of copper imbedded at intervals of one inch. In Fig. 5, h is the fiber block and k is the sliding contact. A watt-hour meter was also installed and the energy input per stroke obtained by measuring the total input for a given number of strokes. It was also necessary to study other hammers in order to make a clear comparison between the electric hammer and the ordinary types.

In the oscillogram of Fig. 7 is shown (between the two vertical lines) the current per phase, a 40-cycle timing wave, and in the middle line is shown the timer. In this oscillogram it is found that the total time required for one complete stroke when the hammer falls down by gravity is $\frac{26}{40} = 0.65$. sec. The time during which power is being admitted is $\frac{8.5}{40} = 0.21$ sec. The average current per phase is 109 amperes.

The energy input per stroke, when falling down by gravity, as found by the watt-hour meter is 1.6 watt-hours. The total height to which the ram and runner were lifted was 1.21 ft. giving therefore a total amount of work, done on the hammer by the motor, of $1.21 \times 275 = 333$ foot-pounds. 1.6 watt-hour $= \frac{1.6 \times 3600}{9.8} \times 7.2$ ft-lb. $= 4240$ ft-lb. giving an efficiency $= \frac{330}{4240} = 7.8$ per cent. In calculating this

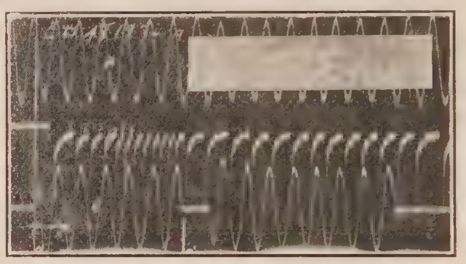

Fig. 9—Oscillogram of Electric Hammer Operating with Full Electric Power on Upward and Downward Parts of Stroke

The upper vibrator gives a smooth wave of a 40-cycle voltage which is used for measuring time. The middle vibrator shows the deflection of a direct current obtained from a dry cell which has its circuit momentarily closed at every inch of movement of the armature or runner. The time taken by the runner to move through one inch is measured by the distance between "making" points which are marked 1, 2, 3, etc. on the record of the approximate zero of the middle vibrator.

The lower vibrator shows the current of one of the three phases.

The distance between the vertical lines A' and B' indicates the time of one complete stroke (or cycle of operation).

Starting at the point A' when alternating current is switched on for the downward stroke the runner starts to fall under the joint action of gravity and electricity accelerating quite rapidly, as shown by the successively decreasing distance between the vertical lines of the middle vibrator, until after six cycles the hammer strikes at about the position marked C'. Shortly after the current to lift the runner is again switched on for a period of eight cycles after which the hammer keeps on moving upward until it practically uses up its momentum and the reversing mechanism operates to switch on the downward power at point B' when the cycle of operation starts to repeat.

efficiency no account is taken of the friction as it was not measured at the time the tests were made. It is very probable that if the friction were considered, an efficiency of about 10 per cent would result. Under the same conditions, the board hammer gives an efficiency of $7.8 \frac{1.6}{3.09} = 4.05$ per cent.

In Table I are given data which were collected in the drop forge shop of the General Electric Company

at Schenectady. From this table we may obtain an idea of what we may expect to be the efficiency of a steam hammer. For instance, hammer No. 32 gave 21,800 strokes in 6.5 hours and only 2971 or approximately 13.7 per cent of the total number of strokes were of use. With an electric hammer this percentage may be raised to 100 per cent and the total efficiency again becomes equal to that of the machine itself as if it were working continuously.

The chart of Fig. 8 gives an idea of the magnitudes of the different quantities involved in the comparison of the two hammers. The weights of the moving part of each of the two hammers are very nearly equal and therefore the comparisons may be made directly. In this chart one assumption is made, that if the board hammer were rated at 1145 lb. it would take four times as much current to lift it as it does at 275 lb. From the oscillograph of Fig. 9 we find that when the electric hammer works with power up and down the total time in which power is being admitted equals 14.5 waves and therefore the power per stroke equals

$$\frac{14.5}{8.5} \times 1.6 = 2.72 \text{ watt-hours.}$$

The comparison between the amounts of energy taken per stroke must necessarily be very rough because the energy per stroke taken by the board hammer is a variable quantity depending upon the amount of useful work it does in a given time that it is running, since it consumes energy while running idle, while the energy per stroke consumed by the electric hammer is constant. The efficiency of the electric hammer therefore is also a constant quantity while that of the board hammer is variable and may reach zero in case the hammer runs idle for a long period of time. It may be pointed out here that since the static condensers are now available at a reasonable price, the total kilovolt amperes drawn from the line may be much reduced by the use of such condensers. Outside of energy consideration, the following qualities have been found very favorable for the electric hammer.

Since there are no moving parts when it is not in operation, it is very much safer than a board hammer. Lately it has been equipped with a reversing knife switch shown at *r* (Fig. 5) and in this way it is possible to obtain any size of blow from zero to 1145 lb. It is obvious that for the small customer, this type of hammer will prove much more satisfactory than an ordinary board hammer which is capable of giving only one size of blow for a given length of stroke. This principle has already been made use of during the period it has been in production work. Therefore the electric hammer is more flexible, is handier, cheaper to operate, probably cheaper in first cost; and while the board hammer has the advantages of the flywheel, the electrical hammer has the advantages of the power on the downward stroke.

Conclusions

To recapitulate, the straight-line motor has proved inefficient for driving railroads, due in part to causes inherent to this type of motors and in part to lack of detailed study relating to the proper construction and to the proper class of railroads to which it should be applied. The motor will, however, prove to be very useful in cases where it is best adapted. The electric hammer is only one of these cases, many others will soon be found and in fact, several of them are already under consideration. I hope in the near future to publish, besides the results of a new hammer now under test, a treatment of this subject under a much broader title in which the electric hammer will appear as a special case of a particular branch of the subject, "The General Motor."

A NEW SYSTEM OF ELECTROMAGNETIC FORCES NEEDED

By Carl Hering
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In liquid conductors, such as exist in some electric furnaces, and especially when high current densities are used, the writer has noticed that there are some new electromagnetic forces which do not appear to be accounted for by present mathematical treatments of the subject; as such very mobile conductors respond more readily to these forces than solid conductors do, they make the presence of such forces more evident; and as most of them presumably increase with the square of the current or the product of two currents, a force which under ordinary circumstances may be unnoticed may become quite formidable at such high current densities. Moreover, for a given current the flux encircling a conductor, which is what gives rise to these forces, becomes greater with diminishing cross sections.

Some of these forces are not only unrecognized by physicists, but they are even denied by them, yet their very evident existence as quite formidable forces requires a satisfactory explanation, and as they may sometimes be usefully applied for mechanical operations in some electric furnaces such as for stirring, circulating, pumping, etc. or at other times may be fatally detrimental to a process, they ought to be duly accepted in treatises; and mathematical treatments of the subject ought to give their quantitative values. Attempts have been made to show that some of them are secondary forces due to a hydraulic action in the liquid conductor; but the writer has shown by numerous experiments that the same forces exist also in solid conductors and cannot, therefore, be hydraulic in the material of the conductor.

Physicists of today, following the definite edict of Maxwell, seem to recognize only one such force, the

one perpendicular to or radial to the conductor, which can, therefore, never have a component longitudinal with the conductor, yet the writer's experiments clearly show the existence of such a longitudinal force even with solid conductors. Just as the so-called and recognized pinch effect (a radial force) tends to crush a conductor radially, so the unrecognized longitudinal force, which the writer many years ago called the stretch effect, tends to stretch or lengthen a conductor, or move it lengthwise.

The reason why this longitudinal force is so strenuously denied by physicists, seems to be that the mathematical treatments of the subject were apparently originally based on what is really only a specific case in which this longitudinal component, although present, happens to drop out of the mathematics because it is zero, as it consists of two equal and opposite forces in that particular case. In all subsequent deductions from such a mathematical treatment, this force can, therefore, never appear again, not even when the two opposing forces are unequal. In the writer's opinion, it is a mathematical error to base a general treatment on a specific case in which one funamental happens by chance to be zero; a general treatment ought to have been based on the general case and ought to contain all the fundamentals. It is well known that like lines of force of the flux repel each other, hence it seems very evident that the disks of flux encircling a conductor should repel each other, thereby tending to straighten, stretch or lengthen the conductor, just as their radial contraction (the pinch effect) tends to crush it radially. When a conductor makes an angle at a hinged joint, a current (if large enough) will straighten it. According to present laws, forces perpendicular to the conductors will act, becoming zero when the conductor is straight. In the writer's opinion the straightening is due to the fact that the flux density in the inner angle, and therefore also the repulsion of like lines of force, are much greater than in the outside angle, hence the straightening; but these forces then continue to exist though now equal, hence the stretching. This force having been dropped out originally in the mathematical treatment cannot now appear even in a case like this one in which it is evidently unequal on the two sides of a conductor. The neglecting of this longitudinal force by physicists for the past fifty years since that edict of Maxwell, may have checked progress in directions of possible importance.

The purpose of the present note is to call attention to this state of affairs and to urge the need of a more general mathematical treatment which should include all the fundamentals. Referring to the diagram, Fig. 1, let P be the point on which the forces act in three dimensional space; let F be a unit line of flux in the X Z plane, encircling a conductor C in the X Y plane and parallel to Y. Then x represents the well-recognized force perpendicular to the conductor; y represents the longitudinal force due to the mutual repulsion of like lines; and z represents the tension along a line of force, or the tangential force referred to in the old statement that a unit magnetic pole will move along a line of force. The force x acts always in the same direction, a pressure toward the conductor; y acts in both directions, being a mutual repulsion of neighboring lines; both are independent of the direction of the current in the conductor; z acts in two directions to contract, like a tensile strain; when the point P is a magnetic pole z acts in only one of two directions, depending on the direction of the current and the magnetic polarity of the particle P; an old experiment states that the pole of a permanent magnet will move in a circle around a straight current-carrying conductor, if given only that particular freedom of motion; the poles of a compass needle will tend to move in the direction of the lines of force of the earth; these are the z forces acting on a magnetic pole.

Experimental cases could be cited in which the freedom of motion is in only one of these three directions, hence only one of these three forces act. In the attraction of iron filings by a conductor, only x acts as the

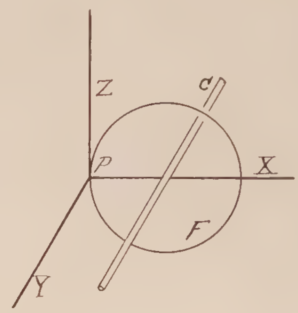

Fig. 1

moving force; in certain electric furnaces y is the chief force, and sometimes x and y together; in the case cited above only z acts. In some cases direct-current produces a mere impulse on closing a circuit, hence with alternating current these successive impulses should and do produce a continuous motion.

A different system might be adopted starting with the tension along straight lines of force, like those between the faces of two unlike magnet poles; in the case of the flux encircling a conductor, the tension along the line of flux would then be the primary one, and the former x force would be a resultant of it, just as the pressure in a soap bubble could be deduced as a resultant from the tension of the film. The repulsion between like lines, y, would be the same as before, and would presumably then be the same in all directions in a plane at right angles to the lines of force. The former z would then drop out.

A general mathematical expression should apply to straight lines also, and not be based on a circle as it may then fail or give infinite or indeterminate values for straight line conditions in which they may be finite. The calculation of the tension of a soap bubble film based on the inside radial pressure would fail when the

film is a plane. The forces between two conductors reside almost entirely in the places where they are nearest together, hence the return conductors or "the rest of the circuit" on which some physicists lay such great and unwarranted stress, may be neglected in practise, if far enough removed. Integrating completely around a whole circuit is often an entirely unnecessary refinement in practise.

It seems that the final abutment, anchorage or fulcrum of such forces must reside in the conductors or in some material body and cannot be in the air or ether; when two conductors make an angle with each other the forces between them (the so-called corner effect) must have their abutments in the conductors, they cannot push or pull against the air or ether. Although not generally accepted, it is the writer's opinion that it will ultimately be conceded that the flux encircling a conductor must be considered to be in some way mechanically (though elastically) integral with its source, the current-carrying conductor, hence the mechanical forces produced by this flux would have their ultimate abutments in their material sources, the conductors which produce them. In an old well known classical experiment a vertical, current-carrying conductor was mounted so that it can be moved parallel to itself by the current in a fixed horizontal conductor beneath it, the motion being in the plane common to both. On the fixed conductor the abutment of this horizontal force must be the encircling flux, which if it were not in some way integrally attached to its source, could not act as an abutment. While the forces may be explained and conceived as being caused by the flux, their ultimate material points of application must be the conductors. What we picture as something which actually exists around a conductor is probably only the action at a distance of something in the conductor.

There are indications that a complete mathematical treatment may show that for any given point P in the diagram, and considering the well known perpendicular force x to be the primary or original one, the other two may be a kind of hydraulic resultants, as though the ether acted as a liquid does, and that x considered as a radial pressure from the left of P may relieve itself in the directions of y or z if the only freedom of motion is in those directions; hydraulic forces can turn corners. A lot of round, slippery rubber rings stretched over a cylinder and having primarily only a radially contracting force, would by slipping over each other exert a longitudinal or stretching force on the cylinder by their contraction.

If this hydraulic action in the ether should prove to be the case, these forces would seem to be numerically equal; the numerical value of the pinch effect seems to be equal to that of the stretching effect, which would mean that $x = y$ for any point P. In the absolute or c. g. s. system, the writer has deduced from the original formula, that the relation of the square of the current divided by the section and the pressure at the center, is unity. Other interesting and useful results might follow from such a proposed general mathematical treatment.

Some of the writer's experiments were described in the *Journal of the Franklin Institute*, November, 1921, p. 599; others are being prepared for publication.

SELLING RESEARCH*

By C. E. Skinner
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Research Department, Westinghouse Electric and Manufacturing Company

When your chairman asked me to talk to you tonight it was his thought that I should give some striking examples out of my own experience to show the value of research. In considering the matter, it seemed to me that it might be more appropriate to speak of a phase of the subject which is seldom mentioned, and I think not generally well understood, namely, selling research or perhaps more properly, selling the products of research. As to the value of research it seems to me that this audience needs no arguments or examples to convince it that research is worth while. If such is needed from me, it should be sufficient to tell you that my company has for quite a number of years expended upwards of half a million dollars a year for research with an ever increasing program for the future. The present industrial depression has somewhat restricted our activities, but our plans for expansion will undoubtedly go forward as soon as business conditions warrant.

It is very difficult to assign money values to the results of many researches which are entirely successful and it often happens that projects undertaken are in themselves unsuccessful. It is rare however that the by-products of a research do not sooner or later pay for it. Our work on magnetic materials has been continuous since our discovery of the phenomenon of aging in 1891. Periods have gone by when there was little apparent progress, but great strides have been made from time to time, and it is certain that our work in the development of low loss, non-aging steel has been worth to the company all that it has cost for all of our research for the last ten years. Through this work apparatus has been cheapened; the user has better apparatus, distributing system stand-by losses have been materially reduced, and this has played some part in the conservation of the Nation's fuel supplies. Who would be able to assign even an approximate money value to the results of such a research? It is even more difficult to assign money values where the results involve the materials and processes generally applicable in the Company's product. Very often such results mean much more to the ultimate consumer than they do to the organization which initiates the research through the cheapening or bettering of the product.

*Address presented at a meeting of the Engineering Division, National Research Council, February 14, 1922.

But I have chosen to talk to you about selling research. Just what do we mean by the term? And why should not research results of value be eagerly sought and used by all who have a place for them? Why should anything like a selling campaign be necessary to market research results? If selling is necessary what rules should be followed in making the sale? Who become the customers? And do the customers have to make a resale? I am not at all certain that I can answer these questions to my own satisfaction, let alone to yours. If I succeed in showing you that selling research is a real research problem, I shall have accomplished at least a part of my purpose.

It is curious and perhaps very desirable trait of human nature that we do not like to accept the results of others without checking them for ourselves to see if they be true. Perhaps we have found errors often enough to justify our lack of confidence.

Again the engineer who can solve his own problem is always loath to utilize anothers solution even though it be a better one, and it is perhaps still harder for anyone to give a really judicial opinion where one's own work is weighed against anothers. Then there is the natural inertia against new things and new methods, and reluctance on the part of those responsible for a given product to introduce any new elements of chance into it, and anything that one has not proved for himself he considers is more or less of a hazard.

I have recently been reading the works of that wonderful research worker and philosopher Henri Fabre, and I can commend the reading of his works to all engaged in research for method, perseverance, and the ability to devise experiments, the results of which will tell him the truth. In no case is he willing to accept the findings of others whether it be a Huxley or a Darwin, except as confirmed by his own observations, but I, recognizing in him a master worker, can accept his finding in most cases without questions.

Selling research therefore consists in convincing all with whom the research worker has to do, that his research is worth while doing, and that the results will show a gain in quality or cost or performance over the methods with which the user is familiar. The master salesman will have far less trouble than the beginner even with the same product. What is said in these remarks will perhaps apply more specifically to research in and for a large industrial organization than elsewhere, but perhaps it may apply to other phases of research as well. The first sale to be made consists in convincing those who are responsible for the financial part of the organization that it is worth while to spend money on the research worker's scheme. Those of you who have to deal with this phase of the subject are well aware of the fact that such a sale is not always easy. Hard-headed business men must be convinced that the results will yield a return before a specific appropriation can be obtained. Those who would use the products of such a research must be convinced that the results will effect a saving or make a better device. A selling campaign is necessary therefore from the inception of the idea until it is fully commercialized. The strategy of such a campaign must be as varied as the researches themselves and must be governed by the circumstances under which the research is undertaken and by the character of the customers with which the research worker has to deal.

In a large organization perhaps the easiest selling campaign is where the results of the research are specifically requested by an individual or a group who have need for such research results and no means themselves for obtaining them. Perhaps the hardest sale to make is where a new device or a new principle is developed independent of the users, and where it requires a change in well-known methods or products to permit its use.

In our own laboratory we have established a group working on heat problems which arise in the operation of electrical machinery, involving heat transmission through the various parts of the machine, particularly the insulation, heat dissipation from surfaces, such as exposed parts of coils, and the removal of heat as by the ventilating system. When this research was undertaken approximately six months were required to establish some of the fundamental methods required. Another considerable period was required to convince the engineers who would use such results that the research worker's figures were trustworthy. Many months more were required to accumulate sufficient data to furnish design engineers with material which they could use to advantage. The general idea was, however, finally sold and a group of design engineers was organized to confer with the research workers to follow the work as it was being carried on, and to direct the program as far as possible, and to see that the results were utilized. The final result has been that the products of this research are sold before the research is completed and any delay in the work is greatly deplored by the engineers who utilize the products.

Your speaker has been interested in high-tension research ever since his carrying on a long series of tests and researches in connection with the original Pomona transmission in 1891 and '92. The large number of projects in the electrical field today, involving such plans as the superpower transmission scheme on the Atlantic seaboard, and the long-distance transmission of power in many parts of this and in other countries, with line voltages already reaching 220,000 and projects on hand for 250,000-volt transmission, make researches in this field very necessary. We have had available for this work for quite a number of years some 500,000-volt transformers which could be connected in series with the middle point grounded to give 1,000,000 volts and results of tests at this voltage were published a number of years ago. There has been a

growing conviction, however, on the part of those responsible for our high-voltage apparatus, that greater amounts of power and better facilities for making such tests should be available. It may interest this audience to know that a group of our engineers worked for a year or more on the selling program necessary to finally bring about the construction of a million volt laboratory entirely adequate for the purpose. When the idea was sold it required the construction of an expensive building, the design and construction of transformers which would give 1,000,000 volts from one side to the ground, the design and construction of all the necessary auxiliary apparatus for adequate control of the tests. This laboratory has now been available for some little time and we are in a position to do research work in this extremely important field with an outfit capable of giving 1,000,000 volts to ground with 1000 kv-a. or more capacity, and backed by a power station which will give adequate power for short circuit testing, with necessary space for work on outdoor devices, etc. The initial cost of the complete laboratory was in the neighborhood of half a million dollars.

As another phase of the selling proposition let us consider the following: Let us assume that from theoretical considerations a brilliant research worker sees that he can utilize a new principle in the construction of a superior lightning arrester. Does every one involved in the engineering, manufacture, marketing and use of the lightning arrester enthuse over the new scheme when it is explained to them? The chances are one hundred to one that few, if any of them, do so. They may be sympathetic but they are not enthusiastic. They would like to see the scheme tried out, provided it does not involve them in any risk, but they may one and all be very backward in recommending the expenditure of money over the scheme. The research worker must then convince the authorities that investigation in the laboratory is worth while. He must convince the engineers that laboratory results correspond to theory and show them that a practical construction is possible. Practical designs must be made and field trials arranged for. Assuming these successful, manufacturing authorities must be shown that manufacture is feasible and profitable, and the sales force convinced that the new device is something the customer will buy and use. It is perhaps only a truism to say that a salesman can not sell goods in which he does not believe and it is certainly true of goods he does not know or understand. Finally the salesman must convince the customer that the new device is better than the old, and to do so he must go back to the principles underlying its operation which were those used by the research worker in effecting the first sales in this long series. It is of course not always necessary for the research worker to carry out all this sale of program, but I think you will recognize that a program such as that outlined is necessary in many cases.

As stated, one of the difficult sales to make by the research worker is that which involves factory processes. How often does one hear the complaint that those who are to use a new process or material spend their energies in showing why the new scheme will not work rather than trying to make it work. This attitude while still existing is I think far less prevalent, at least in our own organization, than formerly, due to a far more sympathetic attitude between the salesman and the customer; in other words, between the research worker and the factory man. There is a natural and perhaps not altogether unfounded suspicion on the parts of workers' executives and the workmen themselves that new ideas and new processes from the outside will get them into trouble, and a single failure on the part of those exploiting such matters will be remembered much longer than many successes.

It is always a question just how far the research laboratory should carry any particular research, and again here, the answer can be given only after consideration of the particular problem when a part of the research involves tests on a large scale, such as, for example, the application of a new principle of ventilation to a large turbo-generator; the fundamental research may be made in the laboratory, but the final trial can be made only on a large and expensive machine. Where the research involves the development of a small new device, such as a radio receiving tube the research may be completed even to the design and construction of the final device in the laboratory, but the final detailed plans will not be accepted by those who are to use them unless the research worker is entirely familiar with the commercial requirements and so shapes his work that it can be fitted in without change to the apparatus with which it is to be marketed. And even here there may be a great reluctance on the part of those who are to manufacture in quantity to accept the specific plans and designs worked out in the laboratory.

Examples almost without number could be cited to maintain my thesis, that selling research products is one of the very important phases of research work. But perhaps enough has been said to illustrate the points in mind and to show that like research itself, no two selling propositions can be handled in identically the same way, and it is therefore necessary to consider each scheme on its own merits. It may be said, however, that in general, the best method of sale is for the research worker to take his customers into his confidence at as early a date as possible and keep them advised as to the progress of this results, and keep them in contact with his methods of work so that they will have confidence in the results which he produces. In other words to sell research results to advantage a sympathetic contact between the research worker, his work and his customer must be established and maintained until the scheme is fully commercialized.

A Relay Recorder for Remote Control by Radio

BY F. W. DUNMORE

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Review of the Subject.—*Relays have been used for many years in wire telegraphy and other electrical work. The practical operation of relays actuated by received radio signals is a comparatively recent development, and has been made possible by the development of the electron tube amplifier.*

This paper describes the development and the operating principles of a type of relay recorder which is designed to operate from the output terminals of a radio receiving set and which may also be operated by any other source of audio-frequency signal.

By the use of special electron tube circuits the audio-frequency signal is caused to operate an ordinary telegraph relay.

In order to avoid the necessity for using a very sensitive relay, designed to operate on currents of a milliampere or less, which would have delicate adjustments and light contacts and spring tension, advantage was taken of an electron tube amplifier, which has now become a reliable radio instrument, to increase the input voltage to the relay circuit thus making possible the use of a simple ordinary high-resistance telegraph relay. The relay device has therefore been developed to operate from the output circuit of any suitable amplifier in place of the ordinary telephone receivers.

The operation of the relay may serve to work a sounder, buzzer, tape register or any mechanism for remote control by radio.

Two types are described. One type is designed to be operated from batteries. The other type is designed to operate entirely from any 60-cycle 110-volt lighting circuit and this feature makes this type simple and inexpensive to operate, durable and practical. Another unique feature is described which is that of tuning to different audio-frequencies whereby any one of three signals, each of a different audio pitch, may be caused to operate the relay to the exclusion of the others.

Curves and diagrams are shown illustrating the principles of operation.

By the use of two of these relay recorders connected in series across the output terminals of a single radio receiving set, two messages sent on practically the same wave length but of different audio-frequencies, have been accurately received simultaneously.

CONTENTS

Type A— For Use With Batteries

1. *Object of Development.* The object of this investigation was to develop a relay which should operate by received radio signals.

2. *Requirements.* To be satisfactory as a relay recorder the device should have the following characteristics: (1) it must be of simple construction with few adjustments; (2) it must be easy to adjust and capable of being put into operation quickly; (3) it must be selective and as free from static and such disturbances as possible; (4) it must be capable of operating at a speed of at least 12 times per second; (5) it must respond to weak signals; (6) it must be of strong design, durable and capable of maintaining its adjustments; (7) it must be portable.

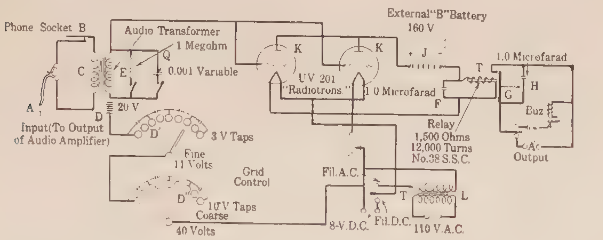

Fig. 1—Circuit Diagram of Relay Recorder for Use with Batteries

3. *Circuit Used.* In order to avoid the use of a very sensitive relay designed to operate on currents of a milliampere or less, with delicate adjustments and light contacts and spring tension, advantage was taken of the radio-audio amplifier (which has now become a reliable radio instrument) to increase the input voltage to the relay circuit, thus making possible the use of a simple ordinary high-resistance telegraph relay. The relay device has therefore been developed to operate from the output circuit of any suitable amplifier in place of the ordinary telephone receivers. The only adjustment necessary is that of an ordinary telegraph relay.

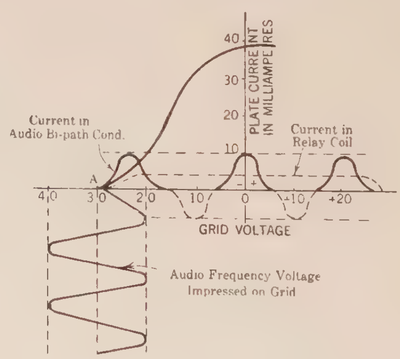

Fig. 2—Tube Charactertistic Showing Principle of Operation of Relay Recorder

Fig. 1 shows the wiring diagram. *A* is a telephone plug for connecting the relay device to the amplifier output. *B* is a phone socket, so that if desired the operator may listen to the received signal in the ordinary way. *C* is an audio transformer of the type used in audio amplifiers, the type used at present being a Signal Corps Type C-21. *E* is a two-megohm, grid leak.

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Q is a 0.0006-microfarad variable condenser or 0.0003-microfarad fixed condenser. D is a 60-volt variable "C" battery variable in steps of approximately three volts. J is a 160-volt dry "B" battery self-contained within the set. K is a type *UV*-201 Radiotron. F and H are each a one-microfarad paper condenser. T is an ordinary telegraph relay rewound with 12,000 turns of number 38 S. S. C. enamel wire. A' is the output to be connected to the apparatus to be controlled. L is a step-down transformer for operating the tube filaments from the 110-volt a-c. supply when such a supply is available.

4. *Principle of Operation.* The principle of operation is illustrated in Fig. 2. By means of the variable "C" battery D, the grid voltage is adjusted to approximately 30 volts at which value the plate current is zero, as shown at A. The incoming audio-frequency voltage impressed on the grid varies the grid potential,

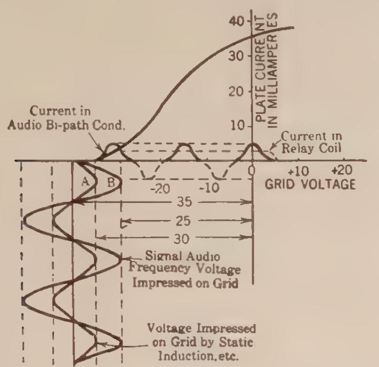

FIG. 3—METHOD OF ELIMIATING STATIC AND INDUCTION NOISES WHICH ARE NOT STRONGER THAN THE SIGNAL

for example, from – 30 to – 20 volts. The 10 volts decrease from – 30 to – 20 causes an increase, for example, from 0 to 10 milliamperes, while the increase from – 30 to – 40 volts is not effective in causing a plate current to flow due to the fact that – 30 volts is already sufficient to reduce the plate current to zero. The result will be a pulsating direct current of 10 milliamperes, maximum amplitude, in the plate circuit. This current, flowing through the plate circuit and condenser F causes an increase in the plate current at the keying frequency, which change, passing through the relay coil will pull the relay armature over, making contact at T, which contact may control any mechanism desired. With the "C" battery grid voltage adjusted for maximum sensitivity it was found that static induction, etc., operated the relay. When these disturbances are not as strong as the signal their effect on the relay may be overcome as shown in Fig. 3. For example, the "C" battery is shown increased to – 35 volts, the critical value for maximum sensitivity being – 30 volts. The disturbances due to stray currents, etc., merely reduce the "C" battery voltage to – 30 which is not sufficient to cause plate current to flow. However, the signal, being of greater intensity than the stray currents, reduces the voltage to – 25 which causes a plate current of five milliamperes. It will be seen therefore that all disturbing effects, if of less intensity than the signal, do not affect the relay.

5. *Method of Increasing Sensitivity and Selectivity.* During the development of this relay it was found that the rectified audio-frequency current in the plate circuit caused the relay armature to chatter rapidly and make a poor contact with the fixed contact point through which the circuit is closed. This was overcome completely, however, by the addition of a one-microfarad condenser across the relay coils. This served the purpose of an audio-frequency by-path for the highly inductive winding of the relay, thus greatly decreasing the resistance of the circuit. The change of plate current due to this audio-frequency caused a second change which occurred at the keying frequency. This latter change passes readily through the relay coils and exerts a strong steady pull on the relay armature without the least chattering.

It was also found that the 0.0006-microfarad variable condenser, Fig. 1, across the secondary of the input audio transformer made possible audio tuning, which increased the selectivity considerable. This tuning was very sharp and it was found that European stations could be made to operate the relay while a high-power station here in the United States would fail to operate it, although the high-power station was coming in on the same wave length and slightly stronger. This was made possible by adjusting the heterodyne note of the European station to a frequency different from that of the local station and then tuning the secondary of the audio transformer to that frequency. The 0.0006-microfarad variable condenser may be replaced by a 0.0003-microfarad fixed condenser and the audio tuning accomplished by adjusting the heterodyne note to the resonant frequency. By means of this audio tuning one of three stations transmitting simultaneously has been selected and caused to operate the relay although all were of equal intensity.

By the use of two relay recorders connected in series across the output terminals of a single radio receiving set, two messages sent on practically the same wave length, but of different audio frequencies, have been accurately received simultaneously.

6. *Speed of Operation.* Tests showed that with a signal strength sufficient to produce a plate current of 10 milliamperes the relay could be operated at a speed of 48 contacts per second, the contact being sufficient to operate a buzzer. With three milliamperes in the plate circuit a speed of 27 contacts per second was obtained. With one milliampere a speed of 19 per second. In each case the relay armature spring tension was adjusted for the best operation.

7. *Sensitivity.* As stated above, this relay was designed primarily with the intention of obtaining a device which should be durable, simple in operation, and strong in construction. Sensitivity is obtained by

means of radio-audio amplification thereby increasing the voltage input to the relay circuit and eliminating the necessity of extreme sensitivity in the relay. Tests at 600 cycles showed that the relay circuit was fairly sensitive, as approximately 1.3 volts at the input terminals of the audio transformer in the relay circuit, caused a current of five milliamperes to flow through the relay coil in the plate circuit.

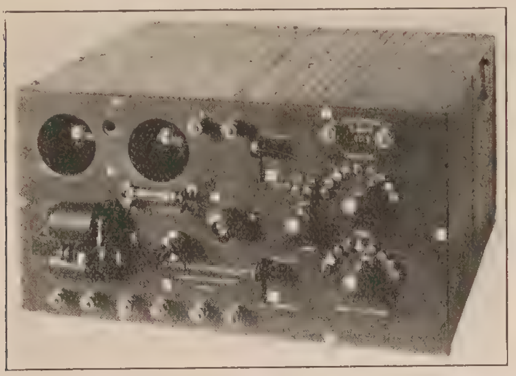

Fig. 4—Type A Relay Recorder for Use with Batteries

8. *Durability.* As the relay instrument used in this recorder is of the ordinary telegraph type its durability is well established. The only elements requiring occasional renewal are the two electron tubes, the 60-volt "C" battery, and the 160-volt "B" battery.

9. *Portability.* The complete recorder with the exception of the filament lighting battery is contained in a cabinet 7 in. by 13 in. by 11 in., as shown in Fig. 4.

10. *Uses.* 1. As an ordinary receiver it has advan-

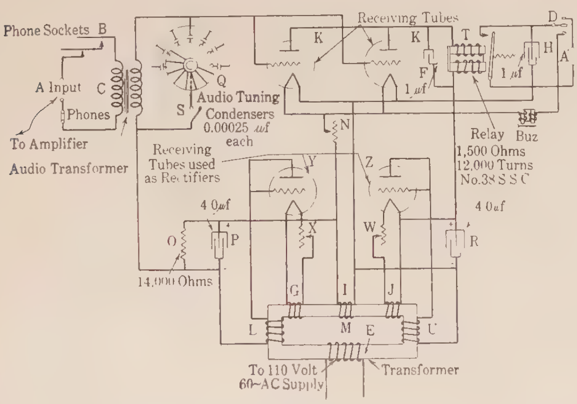

Fig. 5—Circuit Diagram of Relay Recorder for Use on the 110-Volt A-C. Supply

tages over reception with telephone receivers, for one may receive by buzzer or sounder with all induction and interfering noises eliminated (if not louder than the signal.)

2. A tape or drum-type recorder may be used and a copy made without a trained radio operator.

3. Time signals may be recorded.

4. A call system may be worked by a time switch connected to close the filament circuit for a given time at set calling intervals.

5. Any form of mechanism may be operated by an incoming signal.

6. A receiving station may be located remotely from the transmitting station and the radio signals relayed by wire to the operating room some miles distant.

In conclusion it may be stated that a relay of this type should operate satisfactorily, *without attention,* on an airplane where mechanical vibration may be excessive as the pull on the armature with three milliamperes, or over, in the relay coil makes possible the use of a spring tension on the relay armature sufficient to keep it from moving due to mechanical vibration of the relay.

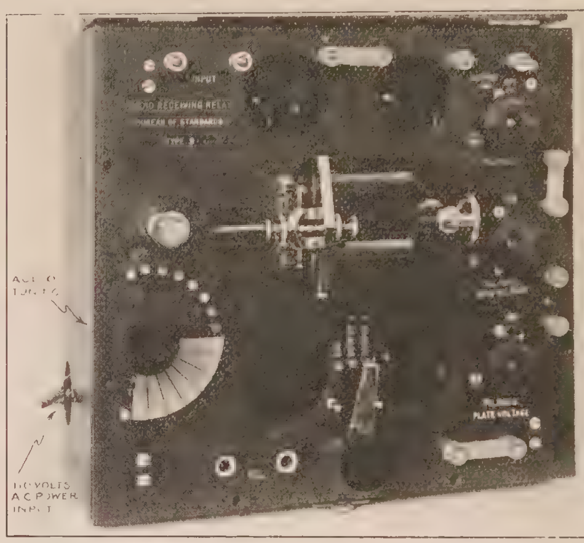

Fig. 6—Type B Relay Recorder for Use on the 110-Volt A-C. Supply

It would seem that the above-mentioned feature makes this remote control relay more serviceable than those now on the market which require delicate adjustment of spring tension, contact points, and suspended vibrating elements.

Type B—For Use on the 60-Cycle, 110-Volt, A-C. Supply

This recorder is similar in construction and operation to the Type *A* recorder, except that the plate and grid voltages (B and C battery) are supplied from the 60-cycle, 110-volt a-c. supply. The current for operating the tube filaments is also obtained from this source, so that the recorder is operated entirely independent of any form of batteries. It is only necessary, therefore, to connect to the 110-volt a-c. line and the recorder is ready to operate.

The method of operating the recorder from the a-c. supply consists in the use of the two receiving tubes as rectifiers as shown in Fig. 5. The tubes *Y* and *Z* are used as half wave rectifiers, one supplying the plate voltage, and the other the grid voltage. When used

as rectifiers, receiving tubes should have the grids and plates electrically connected together. A special transformer M with six windings is used. Two of the windings G and J, supply the filaments of the two rectifier tubes. A third, I, the filaments of the recorder tubes. A fourth, U, the high voltage for the plate. The fifth, L, supplies the grid voltage, and the sixth, E, is the 110-volt primary winding. The rectified alternating current is smoothed out by means of four microfarad condensers P and R, connected across the output terminals. As the currents in the grid and plate circuits are small, smoothing out inductance was found unnecessary. It was found necessary to put 40,000 ohms as shown at O, across the output circuit of the rectifier tube supplying the voltage to the grid, as the grid is otherwise insulated from the filament of tubes K by the rectifier tube. By means of the filament rheostats, X and W, the grid and plate voltages may be varied over any ranges desirable for the most efficient operation of the recorder. By the use of binding posts with straps as shown in Fig. 6, the type B recorder may be operated from A, B and C batteries for supplying the filament, plate and grid voltages respectively in cases where the a-c. supply is not available.

In cases where very high-speed operation is desired, the ordinary relay may be replaced by one designed for high-speed operation.

Electric Crane Controllers

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Review of the Subject.—*Other papers in the series on electrical apparatus for cranes deal with the requirements as to motors and auxiliary equipment; the latter comprising brakes, overload protective panels and limit switches. This paper on controllers reviews its subject in a general way, without going into any details of the devices employed, presenting a clear view of the fundamental considerations involved.*

The controlling apparatus of an electric crane is responsible for the prompt and proper accelerating of the several motions; their speed control; the safeguarding of the motors from abuse; the convenience and economy of operation; and the elimination of many dangers due to carelessness. The author touches indirectly on these points but concerns himself chiefly with the character of the controllers best suited to the bridge, trolley and hoist under various conditions.

The paper deals fully with the problems concerning the selection of ohmic values for the resistors and also covers very completely the connection arrangements and resistance values involved in the dynamic braking control of lowering loads.

CONTENTS

Introduction

THE controlling apparatus of an electric crane is to the machine on which it is used as the nervous system is to the human body.

The best designed and most scientifically selected motors or brakes would be practically useless without the proper means for controlling the energy that must be applied to them to do the work intended. Furthermore, the dissipation of the energy stored in the crane bridge or trolley during acceleration, or in the loads that have been lifted by the hoist, in order to bring these structures to rest, or to lower the loads, is of as great importance as the application of energy in the first place. Friction devices can be used for this purpose, but the resulting wear on the friction surfaces requires frequent replacements and adjustments, particularly on hoists. It has been stated by some one that the energy given up in lowering 20 tons through 50 feet will generate sufficient heat to raise the temperature of 10 lb. of iron 1000 deg. fahr.

It is well-known that friction brakes for lowering were long a source of trouble on crane hoists. Due to the ability of a direct-current motor to convert mechanical energy into electrical energy, as well as to perform the primary function of translating electrical energy into mechanical energy, the motor, in many cases, can be used for retarding also and thus relieve or replace the friction brake for this purpose. The energy is not all radiated from the motor itself, but mostly from resistors connected in the motor circuit. In the resistors the electrical energy is changed into energy in the form of heat, and is transmitted to the air. It is easy to design and proportion resistors to do this without any great depreciation, and the energy can be radiated into the air wherever it is most convenient. There is some additional heating in the motor when used for both applying power and retarding, but on crane work this is not enough to exceed the safe limits of a motor that is large enough to meet the other requirements of starting torque and commutating ability. However, on hard worked cranes and hoists, performing a definite cycle of operations, such as the hoist of an ore bridge, or special cases where loads are hoisted and lowered through long distances, the heating due to the dynamic

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braking current should be taken into account in figuring the size of motor required. On account of the twofold function of the motor, we will consider the question of control in two parts. The first will relate to controllers which are used only where energy is applied to the motor to accelerate and move a load, and which we will call *plain controllers*, and the second to those in which, in addition to accelerating and moving a load, the motor is also used to retard and stop a moving load, and these we will call *controllers with dynamic braking*.

Application of Plain Controllers

Plain controllers are used for either direct or alternating-current motors, and on cranes are usually of the reversing type. The bridge and trolley motions of cranes require controllers of this description. On hoist motions of cranes, with friction brakes for lowering, either reversing or nonreversing controllers will be required, depending on the design of the brake. The first crane hoists were doubtless made with hand-operated brakes for lowering, and if the load on the hook would overhaul the motor, the speed in lowering was regulated by hand or foot, no power being required in the motor during lowering. Mechanical load brakes have been used for a number of years for hoists which are so designed that if the speed of the lowering load exceeds that of the motor, friction is applied to retard it. This form of brake requires the use of a plain reversing controller, but on account of the advantages of controllers with dynamic braking on hoists, it is now used only in special cases.

Direct-current motors are most commonly used for cranes, for the reason that better starting conditions and better speed control can be obtained by their use. Alternating-current motors, usually of the slip-ring type, must sometimes be used because the power supply available is alternating current, and the expense of converting it to direct current may not be warranted. On direct-current cranes the motors for all motions are usually series-wound on account of their strong construction, high starting torque and their characteristic feature of adjusting their speed to the load. Due to friction of gearing, bearings, ropes, etc., there is always sufficient load on the motor to prevent over-speeding, except on overhauling loads on hoists, for which a system of control using a series motor will be described later. Shunt field windings are seldom used, except for bridge or trolley motions where dynamic braking is sometimes required.

Plain controllers for bridge, trolley or hoist motions may be either of the manual or magnetic contactor type. In general, it may be stated that for small motors, or large motors not frequently operated, manual controllers are satisfactory. For motors that are operated very frequently, or for motors of large sizes, magnetic controllers are more desirable for the reason that the small and easily operated master switch relieves the operator of considerable manual labor, and enables him to do more work. Magnetic contactor controllers can also be provided with current limit acceleration, and the motors, as well as the machinery, can thus be protected from damage due to a careless or too ambitious operator attempting to accelerate the motor too rapidly.

The functions of a controller in connecting a motor to the line for operation in either direction are well understood. The controller, either manual or magnetic, should be designed to open or close the circuits with the least amount of wear, and ample provision for taking care of the arc should be made. The wearing parts should be easily accessible for renewals.

On magnetic contactor controllers it is important to have at least two independently operated contacts for opening the motor circuit, so that failure to stop, due to sticking of contactors, will be minimized. This is particularly necessary on hoists, and the addition of a hoist limit switch for positively opening the motor circuit when the hook block reaches the upper limit of travel is desirable from the standpoint of safety to workmen below the crane. Failure to stop the hoist motor often results in breaking the hoisting cables when the hook block strikes the drum or a cross member on the trolley, and the hook block falls to the ground. Even with no load on the hook, men have been killed from this cause.

Calculation of Resistor Ohmic Values

An important point in connection with controllers for cranes is the ohmic value of the resistors used with them. It is well-known that a direct-current motor can not be connected directly across the usual source of power until it has developed a suitable counter e. m. f. Several factors determine the value of the resistor in addition to the requirements for accelerating the motor, gearing and load:

(1) The starting torque required.

(2) The speed control desired.

(3) The protection on reversing controllers when "plugging," which is reversing the current in the armature while running in order to make a quick stop.

On bridge motions the torque, and consequently the current, required to start the motor is usually close to the full-load torque of the motor. On most cranes the ratio of hook load to the total weight of the crane is small, so that the load on the hook does not greatly affect the starting current required. The fact that the load is suspended by ropes also reduces the effect of the hook load in starting. On account of uneveness in the crane runway, even greater current may be required at times. If the resistor for a bridge controller allows less than full-load current to flow, the operator may be obliged to move the controller several points before the motor will start, and there will then be fewer points remaining for speed control. A bridge motor is seldom "plugged," the motion usually being checked by a foot brake, so that a resistor allowing full-load current is satisfactory.

On trolley motions the starting torque and current vary more in proportion to the load, and a resistor allowing less than full-load current is desirable. The trolley motor is usually "plugged" for making quick stops, and the resistor should limit the current to a safe value for the motor under this condition. Low speeds with light loads are also necessary on some trolley motions where it is necessary to place loads accurately. A resistor that will allow half full-load current on the trolley motion is desirable from all three points of view, viz., starting, speed control and "plugging."

On the hoist motion the resistor should allow at least sufficient current on the first point in hoisting to release the brake, and also to give sufficient torque to prevent the maximum load from overhauling, especially where there is no mechanical lowering brake.

The efficiency of a well designed crane may be as high as 70 per cent. The torque and current required to hoist the full load on this crane will be 1/0.70 or 143 per cent of that which would be required to hoist the load if friction were not considered. In lowering, only 70 per cent of the torque, due to the actual load, will be available, so that the lowering torque is about one-half of the total hoisting torque. (70/143 = 0.49 or 49 per cent). While the current required on a series motor to give one-half full-load torque will be somewhat more than one-half full-load current, it is found in practise to be satisfactory to use this value of current on the first point hoisting, as the motor rating should be somewhat more than that required for merely hoisting the maximum load of the crane, in order to allow for acceleration.

This value of the resistor will give a fairly low speed when hoisting a light load, which is an important consideration in a hoist controller. Assuming the light load hoisting current to be about one-quarter of the full-load current of the motor, and referring to the characteristic curve of a Westinghouse No. 7-K d-c. series-wound motor rated at 27½ h. p., 230 volts, the current required would be about 28 amperes. The speed of the motor at full voltage with this current would be 1200 rev. per min. The value of the resistor to allow half full-load current, neglecting the resistance of the motor itself, which is comparatively small, is about 4 ohms. The voltage drop in the resistor is then 28 × 4, or 112 volts, leaving 118 volts on the motor. The speed will then be 1200 × 118/230 = 615 rev. per min. The full speed of this motor is 535 rev. per min. This will be satisfactory in most cases, though there are cases where a much lower speed than this may be necessary, as in the case of foundry controllers where light flasks, or moulds, must be carefully lifted to prevent shaking out the sand. For such service a higher ohmic value of the resistor may be necessary, but if there is danger of the heavy loads overhauling, other provisions, which will be referred to later, will be required. It is of course possible for the operator to move the controller over several points in hoisting the heavy load, but in so doing the number of speed control points remaining is thereby reduced.

As a compromise value for the ohmic value of the resistor, where the manufacturer may not always know the service in which the controller and resistor will be used, about three-quarters of full-load current can be allowed to flow on the first point. This will give sufficient protection if the motor is "plugged" by bringing the controller to the first point in the reverse direction while the motor is still rotating. If the efficiency of the motor is 85 per cent, the back e. m. f. of a motor wound for 230 volts will be nearly 200 volts (230 × 0.85 = 195.5). At the moment current is applied to the motor in the opposite direction, the line voltage will be added to the back e. m. f. of the motor, and there will be a total pressure of 430 volts to force current through the motor and resistor. The value of the resistor to allow three-quarters of full-load current is about 2.7 ohms for the motor to which reference has been made. The current that will flow will be about one and one-half times full-load current (430/2.7 = 159.3 amperes. 159.3/112.5 = 1.43). It is true that on account of the high speed which a series motor will reach on light load, there is a tendency for the voltage to go to a higher value when the field strength is increased by the current that flows when plugging; but the speed of the motor will be reduced about as fast as the field magnetism will build up, so the above voltage may be considered to be about the maximum, and it is the voltage that exists at the moment of reversal. This current will not damage the motor as it must be designed to withstand acceleration peaks as high as this.

The speed reduction obtained with a resistor as just described can be stated as being about 50 per cent for average load conditions. In the case of the Westinghouse motor to which reference has been made, a resistor of about 2.7 ohms would be used. A drop of 50 per cent in the resistor means that the current would be 115/2.7 = 42.6 amperes. 42.6/112.5 = 37.8 or about 40 per cent of full load, which may be considered average load conditions. The motor would run at 850 rev. per min. at this load with full voltage, so that the actual speed would be 425 rev. per min., since there is only half voltage applied to the motor.

In order to secure lower speeds with light loads than can be had with a resistor in the motor circuit, another resistor is shunted around the armature. On manual controllers this can usually be done by adding another contact finger and segment. This has the effect of reducing the voltage applied to the armature and at the same time it increases the field strength. Reductions in speed as much as 90 per cent can be secured in this manner with light loads. Any value of resistor could be used as all of the regular starting resistor is also in the circuit, and any speed could be secured by adjusting the armature shunt. However, if it is made too low, there may be too high a current in the armature and

this resistor if the controller is quickly brought to this point with the motor at high speed. As explained in connection with the current values in plugging, the back e. m. f. may be about 200 volts. It is customary to use a resistor value so that the current will not exceed one and a half times full-load current. For the Westinghouse motor already referred to, with a full-load current of 112.5 amperes, the resistance would be 200/168.75 = 1.18 ohms. In practise it could be somewhat less than this, as the motor would have slowed down somewhat and the back e. m. f. would be correspondingly reduced by the time the armature shunt point was reached. Adjustment of this resistor in the field could be made to suit the actual requirements of speed, load and current allowable.

The resistor values just described are for manual controllers. On magnetic contactor controllers it is customary to allow three-quarters of full-load current to flow on the first point in order to provide protection to the motor when plugging. On most crane controllers full-speed control is used, but the acceleration relay for the first resistor contactor should be set to operate immediately upon closure of the circuit, so that if necessary to secure more torque to hoist a heavy load, or for any other reason, the operator can close this next contactor by means of the master switch. However, the first acceleration relay should be adjusted to prevent the closure of this first contactor in "plugging," if the current is much above the current in starting from rest, so that the "plugging" current will be limited to about one and one-half times full-load current as previously explained.

Resistor Carrying Capacity

The current-carrying capacity of the resistors is another point for consideration. While there are a number of classifications ranging from light starting duty with current on 15 seconds out of four minutes up to continuous duty, there are two classifications that meet the average crane service. The first is light intermittent duty good for one minute out of four minutes, and the second is heavy intermittent duty good for two minutes out of four minutes. These are both on the basis of allowing about three-quarters full-load current on the first point. The first is known as the Electric Power Club rating No. 53, and the second as No. 73. Special cases may require more or less capacity in the resistors. Little is saved on small motors by reducing the capacity below the heavy duty rating, and the use of the heavier duty resistor makes the controller safer for conditions of operation which cannot be foreseen at the time of installation.

On manual controllers there is considerable advantage in having the resistors mounted in the same frame with the controlling elements as there is less wiring required in the crane cab. In all such cases, however, the resistors should be easily removable, both as a unit and as individual units, so that replacements can be easily made.

Controllers with Dynamic Braking

There are two classes of controllers with dynamic braking, first, those used for heavy bridges or trolleys where in either direction it is necessary to dissipate the energy stored in them during acceleration, and second, hoist motions where only in the lowering direction must the energy stored in the load during hoisting be dissipated. In the first case the energy is represented by the well-known formula $\frac{M\,V^2}{2}$, where M is the mass and V the velocity or speed in feet per second. This energy is small, on ordinary cranes, in relation to the energy required to accelerate and drive these motions. "Plugging" is much used on trolley motions because of its effectiveness and absence of any additional control apparatus. On high-speed trolleys of ore bridges, the proportions of this energy to the energy for accelerating and running is much greater, and a controller with dynamic braking may be desirable to reduce the current consumption and provide graduated braking to give smoother operation. On hoist motions the energy to be dissipated is represented by the formula $W \times S$ where W is the weight of the load in pounds, and S the distance in feet the load has been lifted. In lowering, friction of the gearing, bearings, ropes, etc., absorbs part of the energy stored in the load. On a crane hoist having an efficiency of 70 per cent, it has already been shown that the torque in lowering is about one-half that required in hoisting, so the energy is in like proportion.

Direct-current motors are best adapted to all forms of dynamic braking control. A series-wound motor is not well suited for controllers of the first class, where the braking is required in either direction of travel. A series generator is not a very stable machine, especially when operating under widely varying speed and torque conditions. Furthermore, the switching of connections necessary to cause the current to flow in the armature and field in the proper directions for either running or braking, whether in the forward or reverse direction of the machine, makes a complicated controller. By using a compound motor the shunt field will give the initial magnetism in the field without regard to the speed of the armature, which is not the case with the series field. It is usually sufficient to use only the shunt field excitation, and the dynamic braking connections are simple, as it is only necessary then to connect a resistor around the terminals of the armature. This resistor may be variable to give graduated braking torque. If it is necessary to include the series field in the dynamic braking circuit in order to get increased torque in braking, the shunt field should also be used to give the initial magnetism in order to cause the dynamic braking current to build up promptly under all conditions of speed. It is of course possible to excite the series field separately from the line, and so to have the same advantage as

if a shunt-wound field were used, but waste of power in the resistors necessary to do this is objectionable. Usually it is desirable to continue the dynamic braking action at the "off" position of the controller, and in such cases means must be provided for automatically disconnecting the series field from the line when the motor has about come to rest, which complicates the controller. Where a series motor must be used, a so-called "teaser" circuit can be applied to the series field, so that a small percentage of full-load current will flow that will enable the motor to build up the dynamic braking current. There is still the objection that such a controller is complicated, and simpler means are usually to be preferred.

A simple arrangement for securing dynamic braking with a series motor operating in either direction is to use a resistor shunted around the armature as described in connection with plain controllers. The armature will force current through the resistor across its terminals until it has slowed down to a point where its back e. m. f. is equal to or below the voltage applied to it,

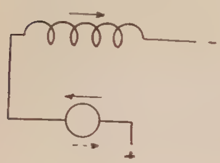

FIG. 1

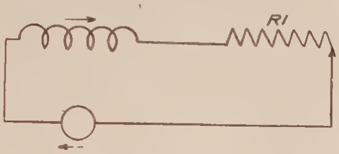

FIG. 2

and it will then continue to run at a greatly reduced speed, so that it can easily be stopped by disconnecting it from the line. A magnetic friction brake may be necessary finally to stop the motor, but on account of the greatly reduced speed the energy to be absorbed by the brake is small. Several points of shunted armature, obtained by varying the resistance, should be used to enable the speed gradually to be reduced without exceeding a safe current in the armature.

Alternating-current motors are not well adapted for use on motions requiring the motor to be used for slowing down and stopping. It requires direct current for energizing the primary circuit during braking, and where alternating-current cranes are installed, no suitable provision for direct current for this purpose would be available, nor would the braking action be as effective or as easily regulated as in the case of the direct-current motors.

It will be seen that this class of controllers with dynamic braking will usually require some application of power from a source outside the motor to give proper braking action. If failure of the power supply should occur at the moment the retarding action was to be applied, either in plugging, dynamic braking or applying a shunt to the armature, failure to stop the motor may cause an accident. Where a series field is connected in the dynamic braking circuit there would be a continued braking action, provided the conditions of speed had been such as to cause it to begin. But, especially in magnetic controllers, which require power to close the contactors, failure of the controller to close the proper circuits may also result. Therefore in all cases where there is any hazard involved if the motor cannot be stopped through its own action, it is advisable to use a friction brake also. A series-wound brake is always the safest, but if the fluctuations in current are too great to permit a series brake to be used, a shunt-wound magnetic brake should be used for safety. If this is connected across the line permanently, so that it sets only in an emergency, the wear on it will be negligible, and it will be in good condition to perform its function as a safety device if occasion demands it.

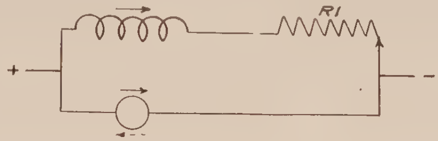

FIG. 3

DYNAMIC BRAKING LOWERING

It is on the hoist motions of cranes and similar machines that controllers with dynamic braking find their greatest application. Since the advent of the present system of control here described, in which the controller applies power for lowering light loads, as well as enables the motor to regulate the lowering of heavy loads, the various forms of mechanical lowering brakes for direct-current cranes have been practically eliminated, together with the expense for their maintenance and adjustment. A series motor has always been considered ideal for the hoist motion. It lends itself readily to the requirements of dynamic braking in lowering, for the reason that its back e. m. f. is in the right direction for lowering without complicated switching connections in the controller.

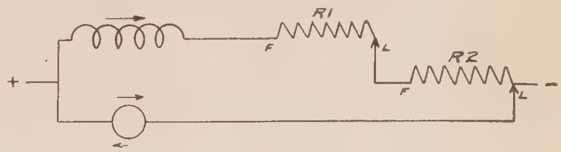

FIG. 4

In the simple diagram shown in Fig. 1, the current in hoisting flows in the direction of the full arrows. The back e. m. f. of the armature is, of course, in the opposite direction as shown by the dotted arrow. In lowering, the armature will rotate in the reverse direction, and the back e. m. f. will be opposite to that first mentioned and current will flow in the same direction as it would in hoisting. This fact helps to simplify the circuit connections required in changing from hoisting to lowering. The connection between one side of the armature and one side of the field is fixed, and this lessens the chances of an open circuit in the controller or wiring of the crane. To complete the dynamic circuit for lowering, we refer to the diagram in Fig. 2.

The circuit is closed through a variable resistor R-1, so that the speed in lowering may be regulated. The value of this resistance depends on the speed desired. The current in the circuit varies with the overhauling load. This circuit is not yet complete, as on an electric crane provision must be made for lowering the empty hook, which may not overhaul the hoisting mechanism. This requires application of power from the line, and we add to the circuit as indicated in Fig. 3.

The series field will now be separately excited from the source of power, and under any condition of load on the hook, a definite amount of field excitation will be assured to enable the armature to generate current. In starting from rest, current will flow in the armature in the direction indicated by the full arrow, and will continue in that direction until driven by an overhauling load sufficiently heavy to overcome the friction of the hoist, and to drive the armature at such a speed that its generated e. m. f. will be greater than that applied to it, when current will flow in the opposite direction. The field strength, and consequently the speed of the armature with any load, depend on the value of resistance R^1. In practise this is found to be about one-half full-load current to give the necessary speeds for light and heavy loads. This same resistor can be used in the hoisting direction, for it meets the requirements of starting and speed control as explained in connection with plain controllers mentioned in the first part of this paper. It will be easily seen that the

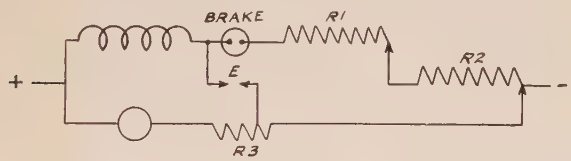

FIG. 5

essence of this system is to excite the series field separately, and so obtain somewhat the characteristics of a shunt-wound motor, which is easily convertible into a generator. There is a great advantage, however, over a shunt motor in the fact that once the motor is started it can easily supply its own field excitation, even at low speeds, because of the variable resistor R^1, and thus failure of the supply voltage does not cause the loss of ability to slow down and stop the motor.

In Fig. 3, no provision is shown for limiting the current in the armature during acceleration. This is provided by another resistor, R^2, which is connected as shown in Fig. 4.

This is also a variable resistor, and by the connections employed it is cut out of the armature circuit and into the field circuit, thus giving greater variation in the speed control. The connections shown are for the last point of the controller, the arrows being considered as moving along the resistors from points marked "F" to points marked "L" as the controller is brought to the full-speed position. The ohmic value of resistor R^2 should be sufficient to limit the current at the start to suitable amounts in the two parallel circuits, viz., armature and field, to give enough torque to start the motor.

It is necessary to use a magnetic friction brake for holding the load suspended, and also for bringing the load to a final stop.

Dynamic braking can reduce the speed of a lowering load to a low value, it is true, but never to a definite stop if there is an overhauling load. A series brake is used on most hoists because it offers the greatest protection if the motor circuit opens accidentally. It is also quicker acting than a shunt brake and requires no additional control wires. It is connected in the field circuit as shown in Fig. 5.

It will be noted that there is an unbroken circuit from one side of the armature through the series field and brake in either hoisting or lowering, so that the chances of losing the dynamic braking circuit by any failure in the circuit-closing contacts of the controller are limited to the connection between the other side of the armature and the brake. On magnetic controllers a spring or gravity closed contactor E is connected in the circuit so that any failure of voltage, or the failure of the hoisting or lowering contactors themselves, will cause the closure of a safety dynamic braking circuit independent of the regular controlling circuits. On manual controllers a similar connection is made in the controller at the "off" position.

It will be noted in Fig. 5 that another resistor R^3 has been added. This is necessary in order to secure the release of the brake under all conditions. On a manual controller especially, if the resistor R^2 were cut out too rapidly, the armature might not accelerate quickly enough, and being in a parallel path with the field and brake, would take most of the current if this resistor R^3 were not used. The brake would not release and with the low field current the armature current would reach a high value. The addition of resistor R^3 causes a more equal division of the current at the first point when starting, and insures the release of the brake even when the operator moves the controller on rapidly. This resistor R^3 also limits the current when the controller is brought to the "off" point quickly, and when the emergency circuit is closed. Theoretically this resistor should be gradually cut out of the circuit until at the full-speed position the armature would be directly across the line. If this were done, the speeds in lowering light and heavy loads would be very nearly the same, and on the heavier overhauling loads some current might be returned to the line. On manual controllers, however, the expense of the additional contact devices necessary is not warranted. On magnetic controllers such provision can more easily be made by the addition of the necessary contactors, and means can also be easily provided for insuring the release of the brake before the resistor is short-circuited. However, it has been found that

unless a certain amount of resistor R^3 is left in the circuit, there will be a tendency for the motor to "hunt," or have an unstable speed for a time, due no doubt to the high armature current flowing at this time, while the field current is comparatively low.

If the current in the field on the last point is limited, by the combined resistors R^1 and R^2, to one-half full-load current, and the resistor R^3 adjusted to give proper operation of the series brake, the speed in lowering the light hook is about 1½ times the rated full-load speed of the motor, while the speed in lowering the full load of the crane is about 2½ times the rated speed. These values may vary with different conditions of friction, number of reductions in gearing and ropes, and the size of the motor with reference to the load upon it, but the ratios stated are for average conditions. The light-hook speed can be increased somewhat by using a weaker field and cutting out part of the resistor R^3 as indicated, but this adds considerable expense for the additional apparatus and is necessary only in special cases. A shunted armature connection can easily be added for the hoisting direction when necessary to secure unusually low speeds at light loads, as already explained in connection with plain controllers.

It should be noted that the combined action of dynamic braking and the friction brake at the "off" position gives double protection in preventing the load from lowering. This combined effect is had also with magnetic controllers in case of failure of voltage or failure of the hoisting or lowering contactors to close and remain closed at the proper time. On manual controllers failure of the voltage will not cause the opening of the dynamic braking circuit as in the case of the magnetic controller. The fact that there is always a dynamic braking action at the "off" position relieves the friction brake of a great part of the work of bringing the motor to rest. In this system of control, the fact that the number of places is few at which it is necessary to open the circuit in changing from hoisting to lowering, makes it a very safe system of control for hoists. All these points have been well proved by the number of controllers of this type now in use. In fact, it has become the standard system of control for the hoist motion of direct-current electric cranes.

Auxiliary Electrical Equipment for Motor-Operated Cranes

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Review of the Subject.—*This is one of a series of papers on the selection of electrical apparatus for cranes and deals with the brakes, overload protective panels and limit switches. Other papers of the series cover the requirements as to motors and control.*

A magnetic friction brake is needed for every crane hoist, in addition to what may be provided in the way of dynamic braking or mechanical brakes, but its required characteristics are very definitely affected thereby. In selecting a magnetic brake the character of the service must be well understood, and the part that it plays therein, and it must possess an adequate energy dissipating capacity. A definite formula for such selection is given.

The paper discusses the various service requirements and describes the several available types of magnet brakes and their particular fields of application.

Limit switches, while occasionally employed to limit the travel of the trolley or bridge motions of a crane, are universally used to limit the upward travel of the hook block. Hoist limit switches may be geared to the machine or directly operated by the block. The former do not take into account the stretching of cables and require complete readjustment when new cables are installed. Switches operated by the hook block are the surest.

The paper describes the various forms of geared and direct-operated limit switches and points out their relative advantages. Considerations of safety often demand that the operation of the switch not only disconnects the motor but simultaneously closes a dynamic braking circuit for quick stop.

The history is given of the evolution of the modern crane overload protective equipment and devices. Fuses and railway type circuit breakers have been tried, but up-to-date equipment employs overload relays in each motor circuit operating in conjunction with magnetic switches. In the interests of safety it is possible to cut off all power instantly by tripping a switch that causes the magnetic switches to open. Safety locks are provided that permit of locking the entire crane equipment against operation.

The best results are secured by properly inspected time-element overload relays in each motor circuit and a common-return instantaneous relay.

CONTENTS

IN addition to motors and controllers, modern cranes also require auxiliary electrical equipment, namely; magnetic friction brakes, overload protective panels and limit switches.

To be presented at the Spring Convention of the A. I. E. E., Chicago, Ill., April 19-21, 1922.

D-C. Magnetic Friction Brakes

Every crane hoist requires a magnetic friction brake for the purpose of stopping and holding loads in suspension. If the crane is equipped with dynamic lowering control, a large part of the work of retardation is absorbed electrically, in the dynamic braking resistance.

In the case of a crane equipped with a well-adjusted mechanical load brake, the magnetic brake is called upon to absorb only the energy of the rotating armature. In the case of a crane without either dynamic lowering control or mechanical load brake, the magnetic brake is called upon to absorb in friction and dissipate in heat, all of the stored energy in the moving load, gearing and armature. The amount of energy expressed in foot-pounds per minute or per hour which a brake of given type and size may safely dissipate without exceeding a reasonable rise in temperature, is a definite quantity. In selecting a brake for severe duty, the above factors should be considered in connection with the severest probable duty cycle, and a brake should be selected whose energy-dissipating capacity provides some margin of safety above anticipated requirements. A failure to observe this simple precaution in the past has often resulted in serious trouble, especially with brakes of poor heat dissipating capacity.

On a crane without mechanical load brake, the magnetic brake is the sole means of holding a load in suspension. It is, therefore, an important factor in the safe and efficient operation of the crane and care must be exercised to select a brake having sufficient torque to hold, and, in case of emergency, to stop the heaviest load which the crane may be called upon to handle. Some manufacturers rate their brakes in horse power, corresponding to the ratings of the motors with which they recommend their brakes to be used. The horse power rating has arisen from the fact that hoist brakes are usually, though not always, mounted on the armature shaft of the hoist motor, and from the fact that the coils for series-wound brakes must be designed on the basis of the motor rating. The torque rating of a brake is, of course, a perfectly definite quantity determined by actual test. The horse power rating is the calculated horse power which the brake would absorb when exerting its rated retarding torque at an assumed speed. The speed is determined by averaging the full-load rated speeds of various makes of hoist motors. As a guide to the approximate size of brake required, the horse power rating is, no doubt, useful but as a basis for the selection of a brake, it may prove positively dangerous. A calculation of the actual torque required to hold the maximum load in suspension should therefore be made and a brake whose torque rating is at least equal to this amount should be selected. This torque can be quickly calculated from the formula:

$$T = \frac{L \times D \times E}{24\,R}$$

where T = Torque in lb-ft.
L = Maximum load in lb.
D = Diameter of winding drum, in inches.
E = Efficiency of gearing.
R = Gear reduction including ropes, between load and the shaft on which the brake is mounted.

Brakes selected in accordance with this plan will, in general have less torque than the motor in connection with which they are used; this is because of the fact that the inefficiency of the gearing is of assistance to the brake whereas it is a handicap to the motor. In order to provide a margin of safety it is therefore customary to select a brake on the basis of motor torque. If the torque rating of the motor is not at hand, or if the brake is to be mounted on some shaft other than the armature shaft the torque can be calculated from the formula:

$$T = \frac{33000 \times \text{h. p.}}{2\,\pi\,N} = \frac{5250\ \text{h. p.}}{N}$$

where T = Torque in lb. ft.
h. p. = Horse power rating of motor
N = Rev. per min. of shaft to which brake is to be attached.

As above stated the hoist brake is usually mounted on the armature shaft of the hoist motor. This is not universally the case, however, and not infrequently brakes are mounted on intermediate shafts. In the case of ladle and hot metal cranes, for example; when dynamic lowering control is used, in view of the great responsibility imposed on the brakes, it is customary for safety reasons, to install brakes both on the armature and on intermediate shafts. Either of these brakes alone should be capable of stopping and holding the load. A brake on an intermediate shaft as compared with a brake on the armature shaft, in order to hold the same load, must develop a greater torque in proportion to the gear reduction.

Intermediate shaft brakes are, not infrequently, too large, or of improper design for the real purpose they are intended to serve. By far the greater part of the stored energy in the system is in the rotating armature. If this energy is absorbed by a brake on the armature shaft, the only parts subjected to stress are the armature shaft and bearings, the motor supports and the brake itself. If this energy is suddenly absorbed by a brake on an intermediate shaft, this shaft, together with its bearings and the gearing, are also subjected to severe stresses. There is always some back lash in the gearing and in consequence, every time the intermediate shaft brake stops the armature, a hammer blow is delivered to the gearing and transmitted to the shafts and bearings. In one direction of rotation this hammer blow is delivered downward and in the other direction, upward, so that the mechanism is continually subjected to alternating stresses of great intensity. On ladle cranes this hammer blow is particularly noticable when hoisting without load, because in this event the motor operates considerably above normal speed. In various installations this effect has been so severe as to break bearing cap bolts, bend shafts, strip pinions and break motor feet. In all such cases, where two brakes are required it is a wise precaution to use a quick acting brake operated by a short stroke magnet, on the armature shaft and a more sluggish brake, operated by a

long stroke solenoid on the intermediate shaft. Since this trouble is most likely to occur in hoisting the light hook, it can be almost entirely eliminated by using a dead-end band brake as an intermediate shaft brake, as this type of brake is practically ineffective when the brake wheel rotates toward the anchored end of the band.

The operating coil of a magnetic brake may be series wound, for connection in series with the motor, or shunt wound for direct connection to the power circuit in parallel with the motor, or compound wound, *i. e.*, having both shunt and series windings. Compound wound brakes are rarely used on electric cranes, though their use may be advisable in special applications in connection with compound wound motors, where the load may approach zero. Shunt brakes are sometimes used on standard crane hoists due to the preference of the individual user, but in general shunt brakes constitute an evil to be avoided where possible in crane service. If wound for full voltage their inductive effect makes them sluggish in action and destructive to insulation. If wound for fractional voltage in order to reduce the inductive effect, the additional complication of a fine wire resistor for connection in series with the coil is required. Their use involves the use of additional trolley conductors. If used in connection with a dynamic lowering controller they are a menace to safety because they may be held released by any one of a variety of causes when it is very necessary that they be applied. From the standpoint of safety it is especially desirable to provide some assurance that the brake will automatically set in case of accidental failure of the dynamic braking circuit. This feature can be secured with the shunt brake only by means of the additional complication of a series relay, whose coil is connected in series with the motor precisely as the coil of a series brake would be connected, and whose contacts are connected in series with the shunt brake-control circuit. Shunt brakes must be used where it is desired to provide a drift point, as on bridge and trolley motions and in some special applications. For crane hoist service, however, the series-wound brake has been all but universally adopted, because of its simplicity, reliability, and suitability, for the work. The sole objection raised against the series winding in the past has been that its operating range is too narrow. Following the introduction of dynamic lowering control, it was found that few brakes in service could be depended upon to release at less than 75 per cent of full-load current. Another objection was that series brakes would not hold released to a sufficiently low value of current. However, these objections do not apply to brakes of modern design which will release at 40 per cent and hold released as low as 10 per cent of full-load current or less.

As regards the mechanical arrangement of their friction surfaces, commercial brakes are of three general types, namely, band brakes, shoe brakes and disk brakes.

The most extensively used type for crane hoists is the dead-end band brake. It consists of a flexible sheet steel band, lined with leather, asbestos composition or other friction material, one end of which is firmly anchored by means of a cast or forged ear, riveted to the band. The other end of the band is attached through a suitable adjustable fitting to a lever, which is operated by a long-stroke solenoid. In most designs the weight of the solenoid plunger, assisted perhaps by an adjustable weight on the lever, is made to apply the brake. In other designs the brake is applied by means of a spring. Very considerable improvement has been made in recent years in band brakes as manufactured by the various crane builders by refinement of the structural details and by the adoption of a well-designed single-coil solenoid instead of the old two-coil horse-shoe type operating magnet formerly used. For some purposes, as for example, on an intermediate shaft, the band brake has decided advantages, and for such applications it will, no doubt, long continue to be used. It possesses, however, inherent defects which no amount of refinement in design can eliminate. The most important of these defects is that it is effective in only one direction of rotation. In lowering, the friction between the brake wheel and band tends to wrap the band more tightly around the wheel, and this together with the fact that almost the whole circumference of the wheel is used gives high braking torque. But in the opposite direction the friction between wheel and band simply tends to raise the operating lever, and the retarding torque developed is practically nil. In hoisting the light hook, therefore, an excessive amount of drift is experienced and many accidents, usually unjustly blamed on the failure of limit switches, have resulted in consequence.

Another defect of the band brake is that it is difficult to make it as strong mechanically as other types. The band must possess a degree of flexibility which limits its thickness and therefore its strength, and the ends where the ears are attached are especially apt to fail. Every one with steel mill experience has seen these bands fail, perhaps with disastrous results. In actual practise the band nearly always drags more or less, imposing a friction load which detracts from efficiency. The long-stroke solenoid is sluggish in action as compared with a short-stroke electromagnet, so that in hoisting a heavy load, when the controller is brought to the off position the load may start to drop before the brake sets. When somewhat out of adjustment and operating through an excessively long stroke the hammer blow developed when the plunger drops, gives for an instant an excessive braking torque which throws severe stresses on brake band and gearing, sometimes resulting in damage to both.

These various defects of the band brake are rapidly forcing the more general use of shoe and disk brakes. The shoe brake consists of a brake wheel and a pair of shoes lined with friction material, and operated

through the proper mechanism by either a short-stroke electromagnet of the clapper type or a solenoid. When a clapper type magnet is used, the brake is set by means of a spring. When a solenoid is used, the weight of the plunger is usually assisted by a spring. The only serious defect of the shoe brake is that it is practically impossible to use much more than one-half of the circumference of the brake wheel as a bearing for the shoes. Therefore, if the pressure per square inch is kept down to a value which will allow long life to the friction material, a considerably larger brake of the shoe type than of the band type will be required for the same torque. As compared with the band brake, the shoe brake has the following definite advantages; it gives the same braking torque in either direction of rotation; it is a stronger mechanical structure, when operated by a short stroke magnet it is much quicker in action and yet has less instantaneous excessive braking; it is easy to keep it so adjusted that the brake shoes do not drag.

The disk brake consists of a set of one or more rotating disks, feather keyed to a hub which is in turn keyed to the shaft to be retarded and a set of stationary disks feather keyed to the frame of the brake. Either the rotating or stationary disks may be faced with friction material. The armature plate of the short-stroke operating magnet is moved forward by a spring, pressing the friction plates together when the brake is applied. When the magnet is energized the spring is compressed, and the friction plates float apart. The positive advantages of the disk type construction are that it gives equal braking torque in either direction of rotation; it provides plenty of friction surface and, therefore, gives relatively high torque in a relatively small and compact structure; because its friction surfaces are enclosed it gives a very constant torque, regardless of weather, splashing, oil or other untoward conditions. Its positive disadvantages are that on account of its compact structure it will dissipate relatively little heat; on account of the necessarily small bearing of rotating and stationary disks on the feather keys, the wear in both keys and keyways is excessive in severe service; the operating magnet simply relieves the pressure on the disks, when the brake is released and does not positively disengage the disks. This aggravates the trouble from heating; if it is desired to replace the armature or other shaft to which the brake is attached, it is necessary to entirely remove the brake.

To sum up, then, each type of brake has its advantages and its particular applications. The band brake should be used where a holding brake is desired. Its excellent torque characteristic in one direction of rotation is a positive advantage in such service. The shoe brake is a general service brake and should be used for all severe duty applications. The disk brake is also a general service brake which will give excellent satisfaction in light duty applications. Its use is frequently dictated by space limitations.

All of the three types of brakes above described are subject to the same objection, namely, that their torque is either all on or all off; in other words, they do not permit any graduation of braking torque. For most applications, this is not a grave disadvantage. Where dynamic braking control is used, the load is retarded by a nicely graduated braking torque and the fixed torque of the magnetic brake is of no consequence. In many cases where no great nicety of control is required, even without dynamic braking control, no difficulty is experienced if the brake is reasonably well proportioned with reference to the motor and the load. In special applications, however, the fixed torque characteristics of the ordinary brake is a very serious disadvantage. For example, take the case of the bridge motion of a gantry crane which it is desired to hold against any probable wind pressure. In such a case, the torque required of the brake bears no definite necessary relation to the motor torque. If a brake sufficiently powerful for safety in emergency is used, entirely too severe braking for ordinary service application will result. The swinging motion of a jib crane or a hammer head crane presents a similar difficulty. A too severe application of the brake produces objectionable and even dangerous swinging of the load, and, sets up excessive stresses in the structure. Various attempts have been made to properly take care of these difficulties. One method is to use a dash pot to secure gradual application of the brake. This is open to the objection that the brake must always be gradually applied, even in emergency when it may be necessary to apply it instantly in order to avert a wreck. A more satisfactory solution is the use of a multiple solenoid or multiple magnet brake.

The multiple solenoid brake consists of practically two brakes in one, one solenoid being arranged to release the greater part of the total braking torque and the other solenoid arranged to release a smaller part of the total torque. Both solenoids may be shunt wound or one may be shunt and one may be series wound, depending upon the convenience of control. There are various methods of controlling these brakes depending upon the particular application in which they are used. Both magnets may be released at once when the controller is thrown to the off position, and the action of the more powerful one delayed by a dash pot so that the smaller brake does practically all of the work of bringing the structure to rest, and the more powerful brake is then effective as a holding brake. A second method is to release the more powerful brake on the first point of the controller and the less powerful on the second point. This scheme permits the operator to secure full braking torque in emergency. A third method consists in releasing the large solenoid on the first point, the small solenoid on the second point and in providing a drift or coasting point on the third control notch at which point neither brake nor power is applied. Many applications where a drift point is very desirable will occur to the reader. It must be

kept in mind, however, that with this scheme both solenoids must be shunt wound, involving at least two additional trolley conductors, and this feature may be very objectionable.

The second scheme mentioned above has a special application in connection with dynamic lowering hoist controllers which deserve particular mention. A defect of the standard dynamic lowering systems of control is that it is difficult or impossible to secure creeping speeds in lowering heavy loads. If reference is had to a dynamic braking speed torque curve (See paper by James A. Jackson, *General Electric Review*, June 1917, page 462) it will be noted that for the motor to develop a dynamic braking torque equal to full load torque it is necessary that the armature rotate at about 35 per cent of full load hoisting speed. In other words, it is difficult to secure more than 65 per cent speed reduction in lowering a heavy load, without dangerously overloading the field windings, whereas 90 per cent speed reduction is not infrequently required. This defect of dynamic lowering control is due to the fact that the retarding torque is proportional to the product of the currents in field and armature. The maximum safe field current must be assumed to be full-load current. In order to develop full-load torque the armature must therefore generate full-load current and it will accelerate to the speed necessary to enable it to generate sufficient voltage to force full-load current through the resistance of the dynamic loop. The minimum safe value of resistance in the dynamic loop is also quite definitely determined by considerations apart from speed control. It is evident, therefor, that the only safe way to reduce the minimum lowering speed with heavy loads is to relieve the motor of some of the overhauling torque. This can be very effectively accomplished by means of the multiple solenoid brake. If the smaller brake remains applied, as outlined in the second scheme of operation mentioned above, on the first point of the controller, excellent speed regulation may be secured, even with the heaviest loads the crane may be called upon to handle.

A-C. Magnetic Friction Brakes

Alternating-current brakes are either of the band or shoe type operated either by solenoids or clapper type magnets, or by small torque motors. In general, what has been said above with reference to d-c. brakes applies with equal force to a-c. brakes. It is to be constantly kept in mind, however, that alternating current cranes are rarely found in exceedingly severe duty, so that defects which may be quite serious in d-c. equipment may be unimportant in similar a-c. equipment. Furthermore, on account of the synchronous speed characteristics of the wound-rotor induction motor, the brake is relieved of all danger of excessive stresses and wear because of the excessive speeds often encountered in severe duty d-c. equipment. On the other hand there is no system of dynamic lowering control for a-c. hoists and many a-c. cranes are installed without mechanical load brakes. In consequence, a-c. brakes must usually absorb all of the energy of stopping the load, and usually they constitute the sole means of holding a load in suspension. A strong and reliable brake is therefore essential.

The constant speed characteristic of the wound-rotor induction motor makes a mechanical brake unnecessary for limiting the lowering speed of an overhauling load. The motor is simply accelerated to synchronous speed and above this speed true regenerative braking is secured and power is returned to the line. On the other hand, if no mechanical brake is used, it is impossible to secure a nice speed regulation in lowering an overhauling load, since no system of control for a-c. motors comparable to dynamic braking control for d-c. motors has been designed. This has led to the development of the solenoid load brake, which eliminates many of the inherent disadvantages of the mechanical load brake and secures effectively the desired accuracy of speed control.

The solenoid load brake consists of a single brake wheel and a single pair of brake shoes mounted in an appropriate frame and operated by two solenoids. One solenoid which is connected in the primary circuit is arranged to entirely release the brake when energized. The second solenoid is connected across one phase of the secondary or rotor winding with some variable resistance in series with it. Since the voltage generated by the secondary of an induction motor varies directly as the slip and since the pull of the solenoid can be made to vary almost exactly with the voltage across its coil, the pull can be made almost exactly proportional to the slip or inversely proportional to the speed. This solenoid is of course arranged so that the pressure on the brake shoes is relieved by the pull of the solenoid, so that when the pull is a maximum, that is when the rotor is at standstill, the braking torque is almost entirely relieved, whereas at high speeds, where the slip approaches zero approximately full torque is developed. The braking torque at low speeds can be increased by increasing the variable resistor in series with the solenoid coil. This resistor is controlled by the contacts of the hoist controller, so that operation very similar to that of a dynamic lowering d-c. controller is secured. In hoisting, the solenoid in the primary circuit is energized and this entirely releases the brake so that there is no braking friction in hoisting. On the first three or four points lowering only the solenoid in the secondary circuit is energized, so that on these points accurate speed control is secured by means of the solenoid load brake. On higher speeds the solenoid in the primary circuit is energized and the braking torque of the solenoid load brake is entirely relieved and the load may be lowered at high speeds by pure regenerative braking. The brake is therefore relieved of wear except when operating at slow speeds and in

slowing down from high speed to low speed. As compared with a mechanical load brake, very much less wear due to friction is encountered and much less frequent adjustment is therefore necessary. The solenoid load brake will give as good results on creeping speeds when lowering loads as the mechanical load brake, assuming equivalent adjustment; especially accurate control is secured in lowering a heavy load a very short distance, usually called "jogging".

In conclusion it seems advisable to emphasize the importance of substantial and capable braking equipment on electric cranes. A good dependable hoist brake is perhaps more important from the standpoint of safety than any other item of electrical equipment on a crane. This subject deserves more consideration than has hitherto, in general, been given to it. The brake is an insignificant item of cost in the total price of a crane, so that even a cheap crane could well afford a good brake, but it has been very largely overlooked by the purchasers of cranes and many unsatisfactory and even unsafe brakes are in daily use. If this paper serves in any degree to direct more careful consideration to the matter of magnetic brakes for cranes, the author's object will have been accomplished.

Limit Switches

The function of limit switches as applied to electric cranes is to limit the travel of either hoist, trolley or bridge motion in either one or both directions. Their most common use is to limit the upward travel of the hook block.

Hoist limit switches are of two general types; first, geared; second, direct-operated by the hook block. Geared limit switches consist of a contact mechanism connected to the drum shaft through some such reduction gear as a traveling nut, worm and gear or interrupted gear. This contact mechanism is usually designed to handle a control circuit only, so that in addition to it, a magnetic switch or circuit breaker to break the motor circuit is required. Direct-operated limit switches are of either the control circuit or the main circuit type. The control circuit type consists of a simple normally closed contact opened directly by the hook block, and a magnetic switch. The main circuit type consists of a more substantial contact mechanism, capable of handling the motor current, operated directly by the hook block. It may simply open the motor circuit, or it may in addition provide some form of dynamic braking to secure a quick stop.

As mentioned above, geared limit switches are supplied with either a magnetic switch or a circuit breaker, of the shunt trip type, to open the motor circuit. A sharp distinction must be drawn between these two types. If a shunt trip circuit breaker is used, the geared contact mechanism must have normally open contacts. When the hook approaches the limit of travel, the contacts are closed, the shunt trip coil energized and the circuit breaker thus opened. It is therefore dependent upon the integrity of its circuits for its operation. Its contacts may be out of commission, a shoe may fail to make contact with a trolley bar, or a connection may be loose and the limit switch is inoperative. The important point is that it gives no previous warning or indication of its condition and the hoist may continue to operate until the hook block over-travels and an accident results.

The device with normally closed contacts and a magnetic switch, on the other hand, is normally safe. The magnetic switch will be opened by any failure of the limit switch circuit and the hoist cannot be operated until the fault is repaired. The magnetic switch may of course be held closed by a grounded circuit, independent of the action of the limit switch contacts and thus cause a wreck. However, the danger of grounds is small as compared with the many possibilities of open circuits and the closed circuit device is therefore a much safer and more dependable limit switch than the open-circuit device.

The magnetic switch may be mounted either upon the trolley or in the operator's cab. There is some advantage in mounting upon the trolley. It may not be so easily tampered with and the control wiring runs only a short distance so that there is less danger of grounding. If the magnetic switch is mounted in the cab, it is a wise precaution to put it in a locked enclosing case, so that it cannot be tampered with by unauthorized persons.

The method of resetting the limit switch is important. Any method, such as the use of a push button, which will permit further hoisting after the limit switch has operated, is to be condemned. A control circuit wire, energized by a finger in the hoist controller is often used, and is an excellent method if the necessary contact finger in the controller is available. This connection simply short-circuits the limit switch contacts when the controller is thrown to the lowering position, and the limit switch is reset automatically when the hook has lowered a short distance. A still better method is to connect the main contacts of the magnetic switch in a part of the circuit which is used only in hoisting. It is possible with most reversing controllers and with all dynamic lowering controllers, to make this connection and with this arrangement no control circuit connections whatever are required for reset. It is needless to say that careful and constant inspection is necessary if such limit switches are to be depended upon. The mechanical parts of the contact mechanism require especially close inspection. A flexible coupling of some sort is required between the drum shaft and the operating shaft of the limit switch, because of difficulty in securing accurate alignment. The couplings in general use at the present time are of poor design and are sure to give trouble unless frequently inspected and replaced when necessary. The bearings of the operating shaft require thorough lubrication. Accidents occur because these bearings become

so badly worn that the reduction gears fail to mesh and the contact drum is therefore not driven.

All geared limit switches are open to the very serious objections that they take no account of the stretch of the cables and require complete readjustment whenever new cables are installed. If the limit switch is set with a new cable, to stop the hook travel at the proper level, it quickly develops as the cables stretch that it is impossible to hoist to the desired height, and readjustment is necessary. The direct-operated control circuit type limit switch avoids this difficulty and in addition has the advantage of being a very simple and strong device, and of being subjected to very little wear, because it operates only when the hook reaches the limit of travel. The contact mechanism hangs under the trolley and at least a superficial inspection of it can be made from the floor. For cranes equipped with shoe or disk brakes, giving full braking torque in the hoisting direction and where from twelve to eighteen inches of variable drift may be permitted, this type of limit switch makes very satisfactory equipment. It provides a very considerable degree of protection at very little expense. It is important to remember, however, that a good disk or shoe type brake is very necessary for the reliable operation of such a limit switch.

The extensive use of band brakes, which provide almost no retarding torque in the hoisting direction, and the close limits within which many crane hoists have to work, has lead to the development of direct-operated main circuit limit switches, which in addition to opening the motor circuit, establish dynamic braking connections, in order to secure a quick and accurate stop.

The first devices of this kind were developed in the steel industry which is still their principal field of application. The first development, known as the 2 by 4 limit switch consisted simply of two pieces of 2-in. by 4-in. lumber from two to four feet long connected together at one end by a common door hinge and having mounted upon them at their other ends a pair of carbon blocks. This device is swung under the trolley with its contacts normally open, in such position that the contacts will be closed by the hook block lifting the lower two by four as the hook approaches its limit of travel. The electrical contacts are connected to short-circuit the armature when closed. The tremendous rush of current in the field and the heavy circulating current in the armature brings the hook almost instantly to rest. At the same time the circuit is supposedly opened by the blowing of the circuit breaker in the cab. To reset this limit switch it is necessary to pry the 2 by 4's apart while the hook block is lowered out of the limit.

This limit switch which is extremely effective in securing a quick and accurate stop, is cheap, strong and easily inspected. But it is evident that the operation of such a limit switch must be considered a serious emergency. In addition to the time and trouble required for resetting, the damage accruing to the motor is a serious matter. A flash-over almost inevitably results and after a very few operations of the limit switch the motor must be sent to the repair shop. Furthermore, under certain conditions of operation it is ineffective. If the hoist controller is not in the full on position, that is, if the current in the field circuit is limited by a portion of the starting resistance, the armature will be slowed down but will not be brought to a stop unless the circuit breaker happens to blow. If power fails, or if the hoist controller is brought to the off position at the instant the hook strikes the limit, the switch is absolutely ineffective. This latter contingency is more than probable since an operator will instinctively throw his controller to the off position when he sees the hook approaching the danger point. Very frequent failure of this type of switch may therefore be anticipated and has actually resulted in practise.

This device scarcely deserves consideration here except for the fact that it has served to direct the attention of control manufacturers to the need for a limit switch designed to give quick and accurate stops. The first development along this line consisted of a switch built along the lines of a drum controller, arranged to break the line connections and reconnect the motor with armature reversed as a series generator with a current-limiting resistor in circuit. By adjusting the resistor, practically any degree of braking and therefore any quickness of stop desired may be secured. In the interest of reliability it is wise to use a resistor of non-breakable material, since it must be mounted upon the trolley and since the quick dynamic braking stop depends upon the integrity of this resistor. This type of stop is widely used and gives excellent satisfaction. The objection to it is that it must be reset by hand, and for this purpose a reset rope is provided. The trolley must be run back toward the operator's cab so that the operator can reach the rope which results in some inconvenience and delay. To escape this objection, self-resetting, direct-operated switches have been designed. These switches secure dynamic braking in the manner described above, but in addition, close contacts which establish connections for lowering when the controller is thrown to the lowering position. The hook is lowered at low speed with a shunt around the motor until the hook is out of the danger zone, when the limit switch is automatically reset by a weight and the hook may be lowered at full speed.

If it is necessary to secure a very quick stop, say within four to six inches of drift with the light hook, the dynamic braking resistance will have to be so small and the braking current so heavy, even with this type of limit switch, that the commutator will be pitted and flash-overs may result. If the resistance is so proportioned as to allow a dynamic braking current equivalent to full-load current, only full-load braking torque is generated initially, before the motor begins to

slow down and the average braking torque will be only about half full-load torque. Since the dynamic braking torque is proportional to the square of the current it is evident that about 150 per cent full-load current must flow on the dynamic braking peak in order to secure even as quick a stop as would be secured with a full-torque magnetic friction brake without the assistance of dynamic braking. It is evident, therefore, that by far the best results will be secured by using a good brake of the shoe type in conjunction with the dynamic braking limit switch where very accurate stops are required. Thus with a dynamic braking peak of 200 per cent and a full-torque magnetic brake, an armature rotating at twice full-load speed should be brought to reset in about two-thirds of a second. If the hook speed is fifty-feet per minute, the drift will be about six inches.

As may be seen from the foregoing, the whole matter of hoist limit switches is in a rather chaotic condition at the present time. There is no conclusive and definite opinion among operating men as to what constitutes a good limit switch. Some operating engineers take the position that no limit switch is thoroughly dependable and that a limit switch which is not dependable is worse than none at all. Some maintain that the operator should not be permitted to depend upon the limit switch and that he should be put to some trouble to reset it, so that he will avoid using it if possible. Others maintain that such loss of time in resetting is not permissible and that automatic reset is positively necessary. Still others consider the matter of slight importance and accept without question anything in the way of a limit switch which the crane builder may provide. New cranes are being installed every week with every type of limit switch mentioned herein, from the open-circuit geared type, which the author frankly believes to be worse than no limit switch at all, to the most elaborate form of dynamic-braking direct-operated, self-resetting type. There is literally no standard specification for limit switches either as regards structure, as regards functions or as regards what they shall accomplish. In the hope, therefore, of assisting in the formation of a definite sentiment on this subject, the author ventures to submit his own opinions as follow:

Hoist limit switches should be operated directly by the hook block and should preferably open the motor circuit without the intervention of a magnetic switch or circuit breaker. On cranes equipped with disk or shoe type magnetic brakes and on which the drifting space is ample, a limit switch which merely opens the circuit is sufficient. On cranes equipped with band brakes and on cranes operating with very small head room dynamic braking limit switches should be used. The head room used by upward drift of the hook when retarded from three times rated speed by a full-torque brake, amounts to about three feet when full load speed is 60 feet per minute, 18 inches for 30 feet per minute, and so on in proportion. The above applies when high-speed motors of the so-called crane type are used; about one-half the drift would occur with the lower-speed so-called mill type motors. Hoist limit switches should always be considered emergency devices. Their use for service stops should be discouraged. The most obvious method of discouraging their continual use is to put the operator to some inconvenience in order to reset. It should not be necessary, however, for the operator to climb upon his trolley or endanger himself in any way, and it should not be possible for him to reset and continue to hoist either by accident or intention. It should be effective regardless of power failure or the position of the controller at the instant of operation. The operating mechanism should be positive, and no dependence should be placed upon springs or other mechanism exerting a definitely limited operating force. Direct operation through push rods or steel cable is preferable. In the limit switch itself, simplicity and strength are of the utmost importance. In the purchase, installation, operation and upkeep of a limit switch it should be constantly kept in mind that it is primarily a safety device upon which the safety of human life may very frequently depend and that therefore the best is none too good.

The foregoing has all been with reference to limit switches for limiting the upward travel of the hook. Where a lower as well as an upper limit is required, commercial types of direct-operated stops are not easily applied. In such cases it is customary to use two complete geared limit switches, or a single geared mechanism, such as is used with elevators, containing two adjustable sets of contacts working in conjunction with magnetic switches.

Limit switches are sometimes required to prevent the collision of trolleys on double trolley cranes, or of the cranes themselves when several cranes are mounted upon one runway. Direct-operated dynamic-braking switches have been applied to some extent for this purpose. Another method is to equip the trolley or bridge motors with magnetic friction brakes, normally held released by shunt-wound magnet coils and automatically applied by means of a direct-operated contact device when the machines come into dangerous proximity to one another. This problem, however, does not often arise.

For alternating-current cranes, the same remarks which have been made regarding direct-current cranes apply insofar as they refer to the method of mounting, of operating and of opening circuits. Dynamic braking cannot be secured with an alternating current motor, independent of an outside source of power and the remarks made regarding the use of dynamic braking limit switches therefore do not apply to alternating-current cranes. Fortunately the a-c. motor does not run at a very much higher speed on no-load than it does on full load. The amount of drift is therefore quite constant independent of the load on the hook, so that, if reliable brakes are used, quite accurate

stopping may be secured with direct-operated limit switches which merely open the circuit.

Direct-Current Crane Protective Panels

It has always been the practise to equip electric cranes with some form of protective panel, mounted in the operator's cab, provided with a service knife switch for disconnecting all of the circuits on the crane from the power lines and with some form of individual overload protection for each motor. A vast improvement has been made in recent years in the character of this equipment as offered by the electrical manufacturers, but cranes are still sometimes provided with protective panels of the crude original type. We will, therefore, take up the various types of crane protective panels in the order of their development since even the crudest type is still sometimes furnished on an otherwise modern crane.

The simplest form of crane protective panel consists of a main knife switch with open link fuses and a link fuse in one side of each motor circuit. The unsatisfactory and unsafe character of this equipment scarcely requires comment. The first step in advance from this type is, naturally the use of enclosed fuses instead of link fuses and in this form the fused crane protective panel is very widely used. The protection furnished by this equipment, however, is not very great, and in the case of severe duty cranes is, in fact almost negligible. On severe service cranes heavy momentary over loads are a necessary incident of normal operation. It is, therefore, necessary to use fuses of such large capacity that they afford no protection to the motor or mechanical equipment against continuous overload. For example, a bearing cap in the bridge drive may be pulled up too tight, imposing an overload of 25 or 50 per cent on the bridge motor. In such an event, a fuse, as ordinarily used, in the bridge motor circuit would be unlikely to afford any protection to either the motor or bearing. The panel may be properly fused when new, but it is unlikely to remain so very long. Proper replace fuses often are not at hand when required, and in this case a piece of copper wire is commonly used as a re-fill, which may be replaced at some distant date or not at all. If rigid inspection is enforced and an attempt is made to use fuses of the proper capacity to afford real protection, the replacement of enclosed fuses on a severe duty crane is a considerable item of expense. These disadvantages all indicate the fundamental unsuitableness of fuses for the protection of crane motors and have to some extent forced the adoption of circuit breakers.

Railway type circuit breakers have been used to some extent in this service, in various combinations, and it is rather remarkable that their use is not more general. They constitute a strong and simple protective equipment at comparatively small expense. They avoid the two most important defects of fuse protection, because they may be quickly reset at no expense. The sole serious objection to them is that they must be set too high to give any protection against continuous overloads.

The modern crane protective panel, now almost universally used in the steel industry, has been developed with the view of providing safety protection for the operating force as well as electrical and mechanical protection for the crane. In the interest of safety in emergency it is often desirable that the operator be able to cut off power instantly. This is best accomplished by push button operation of the circuit breakers with the push button mounted within easy reach of the operator. In the interest of safety of workmen engaged in routine inspection and repairs it is desirable to provide means for making it impossible to accidently start any motion of the crane. This is accomplished by providing a safety plug, which the workman takes out of the panel and carries with him in his pocket, while he is on the crane and the absence of which from the panel makes it impossible to close the main circuit breakers; or by providing a safety lock clip on the service knife switch by means of which the workman locks the knife switch in the open position with a safety padlock, the key of which he carries in his pocket. Overload protection is secured by means of overload relays in each motor circuit operating in conjunction with magnetic switches. Various combinations of overload relays are used, depending upon the preference of the user. However, a quite definite standard specification seems to be forming and the type now most generally used has one overload relay in one side of each motor circuit and one common or totalizing relay in the opposite side of the main circuit.

On account of the ease and quickness with which this magnetic contactor type of circuit breaker can be reset it is possible to set the overload relays so that they will trip at a comparatively small overload without interfering too greatly with normal operation. Such a protective panel, therefore, affords some protection against continuous overloads. A much greater degree of protection is secured by the use of inverse time element overload relays. It has become quite common practise to use one inverse time element overload relay in each motor circuit to protect the individual motors against continuous overloads and an instantaneous trip relay in the common or return side of the circuit. This arrangement undoubtedly provides the ideal protection if the equipment is kept in good operating condition, but with the care which such equipment commonly receives in service, it is not wise to put too much reliance upon it. The inverse time element characteristic is usually secured by means of an oil dashpot and its accurate operation depends upon the use of a specific oil having very definite physical characteristics. If some other oil is used the inverse time element feature becomes unreliable or useless. The use of oil moreover tends to assist in the accumulation of dust and grit on the apparatus, which tends to destroy not only the

reliability of the inverse time element feature but in addition may retard or actually prevent the operation of the relay itself. The author does not wish to be understood as condemning panels which make use of inverse time element overload relays. If carefully inspected and kept up they certainly provide a very valuable protection, which can be secured in no other way. Our desire is to emphasize the necessity for this inspection with existing types of equipment, and further to present the problem of securing the time element feature in some more simple and more reliable way.

The selection of the proper sizes of knife switches and magnetic contactors for crane protective panels is of importance. In general it is impossible to calculate with any degree of accuracy the current which, flowing continuously would produce a heating effect equivalent to the varying loads on the several motions. Each motor is operated intermittently but usually not in any definite cycle. Two or even three motions may be operated at the same time. There are so many variables depending upon the infinite variations of actual service that an attempt to standardize at first seems hopeless. However an examination of heating curves on a standard line of 30-min. rated enclosed crane motors shows that they can work at their rated load less than 20 per cent of the total time; also that they will, with rare exceptions, and that on small sizes only, carry no more than 35 per cent of their rated load continuously. This indicates that no matter how the currents flowing to the several motors on the crane are superimposed on one another, the root-mean-square value of the current passing through the main knife switch and magnetic contactors, could not exceed 35 per cent of the sum of the rated currents of the several motors, provided the motors were of such capacity as never to be overheated themselves.

Actual experience, quite independent of the consideration of motor ratings, has evolved a standard which is now in general use. The rule is to use magnetic contactors and main line knife switches whose continuous rating is equal to 50 per cent of the sum of the half-hour current ratings of the several motors on the crane. This rule may be used with confidence in making specifications for crane protective panels for all general purpose cranes having three or more motors. Discretion must of course be used in connection with unusual cases. The arc rupturing capacity of the magnetic contactors, should not be less than three times the normal current of the largest motor on the crane.

Alternating-Current Crane Protective Panels

The problem of overload protection for alternating-current cranes is entirely different from that presented by direct-current cranes. In the first place, an alternating-current motor does not need to be protected against exerting too great a torque instantly. It will inherently stall at somewhere between 2½ and 3½ times full load torque, whereas with a d-c. crane motor, torque can be developed to the destruction of motor or gearing unless a protective device of some sort intervenes. An overload device is therefore required in connection with an a-c. crane motor almost solely for the electrical protection of the motor, and not as on d-c. cranes for the mechanical protection of the motor and gearing. In the second place, in an a-c. crane motor greater starting peaks of current are required for the same motor output than in a d-c. motor, so that any overload device which is unable to differentiate between excessive peaks and continuous overloads of lesser magnitude, is even less useful for the protection of an a-c. crane motor than for a similar d-c. motor. In addition to these considerations, the use of fuses is especially to be condemned in connection with a-c. crane motors because of the danger of single phasing, which might easily result in serious accident.

The satisfactory protection of an a-c. crane therefore depends upon the use of reliable inverse time element overload relays. These relays are usually of the duplex type, that is, with two coils operating upon one control contact. One such relay should be used in the primary circuit to each two- or three-phase motor and in addition, a totalizing relay, connected in series with the wire or wires not protected by the individual motor relays may be used if desired.

HYDROELECTRIC POWER FOR BOISE CITY

The City of Boise has been granted a preliminary permit for a power project on the North and South Forks of the Fayette River, Idaho. The proposed scheme contemplates a complete hydroelectric development of 8000 horse power capacity on the North Fork of the river to be followed by development of 4000 horse power on the South Fork as soon as market conditions warrant.

The project on the North Fork includes a diversion dam 75 feet high, which will create a storage of 2300 acre-feet capacity. A seven-foot pipe line extends downstream from the dam for one-half mile and connects with a tunnel 1000 feet in length, which will be driven through the mountain dividing the North and South Forks of the river. The power house will be located on the South Fork. The turbines will operate under a head of 250 feet.

The development on the South Fork of the river includes a diversion dam 50 feet high which provides 1200 acre-feet of storage. An eight-foot pipe line will lead from the dam 4000 feet downstream to the power house where 4000 horse power can be developed under a head of 97 feet. All generating equipment is to be housed in a single power house. It is proposed to build a 38-mile transmission line to convey power for general municipal and public utility purposes in the City of Boise.

JOURNAL OF THE American Institute of Electrical Engineers

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

A. I. E. E. Spring Convention

CHICAGO, APRIL 19-21, 1922

As previously announced, the Spring Convention of the A. I. E. E. will be held in Chicago, April 19-21, 1922, at the Drake Hotel, which will be the Institute headquarters during the meeting.

Wednesday morning, April 19th, will be devoted to the registration of members and guests. In the afternoon there will be a technical session, at which three papers will be presented, and the evening will be devoted to a social entertainment in the form of a theater party, tendered to the visiting members and guests by the Chicago Section.

On Thursday morning the second technical session will be held, at which three papers will be presented, and in the afternoon there will be a symposium on "Transmission of Energy from Coal Mines to Large Centers of Distribution." A number of engineers will speak briefly, choosing some phase of this subject which has occupied so much attention during the past few years. Some of these phases are—"Energy Transmitted by Coal in Cars, by Electricity, and by Powdered Coal and Pipes." Thursday evening a dinner dance will take place for the members and guests of the convention.

Friday morning, April 21st, there will be the third technical session, at which four papers will be presented, and the afternoon will be devoted to visits to local engineering works of interest. The final session will occur on Friday evening, with a symposium on "The St. Lawrence Seaway." Invitations have been extended to speakers, who represent several phases of this subject, such as navigation possibilities, power possibilities, engineering plants, viewpoints of the Government, of the New York barge canal, of financial interests and of power users.

The complete convention program is as follows:

PROGRAM

Wednesday Morning, April 19

Registration.

Wednesday Afternoon

TECHNICAL SESSION

Opening Remarks by President McClellan.

(1) *The Electric Hammer*, by P. Trombetta.

(2) *A Relay Recorder for Remote Control by Radio*, by F. W. Dunmore.

(3) *Magnetic Flux Distribution in Transformers*, by K. B. McEachron.

Wednesday Evening

Theater Party at the Invitation of the Chicago Section.

Thursday Morning, April 20

TECHNICAL SESSION

(4) *Air-Break Magnetic Blow-Outs*, by J. F. Tritle.

(5) *The Effect of High Currents on Disconnecting Switches*, by H. C. Louis and C. T. Sinclair.

(6) *Characteristics of Insulation*, by Karl W. Wagner.

Thursday Afternoon

SYMPOSIUM

Transmission of Energy from Coal Mines to Large Centers of Distribution.

Among the speakers who will be present are Messrs. Henry Flood, L. E. Imlay, F. G. Clark, P. Junkersfeld, A. H. Armstrong, I. E. Moultrop, R. F. Schuchardt.

Thursday Evening

Dinner Dance.

Friday Morning, April 21

TECHNICAL SESSION

(7) *Selection of Electrical Apparatus for Cranes*, by R. H. McLain.

(8) *Auxiliary Electrical Equipment for Motor-Operated Cranes*, by H. W. Eastwood.

(9) *Electric Crane Controllers*, by J. F. Schnabel.

(10) *Electric Power Application to Passenger and Freight Elevators*, by H. P. Reed.

Friday Afternoon

Visits to Places of Engineering Interest.

Friday Evening

SYMPOSIUM

The St. Lawrence Seaway.

Among the speakers who have already accepted invitations to be present are Messrs. Julius Barnes, H. I. Harriman, Hugh L. Cooper; other prominent speakers are expected to be present.

A. I. E. E. Annual Convention

NIAGARA FALLS, JUNE 26-30, 1922

The Annual Convention of the Institute to be held at Niagara Falls, Ontario, during the week of June 26-30, is expected to be one of the best attended conventions which the Institute has ever held on account of its central location, the natural attractions of Niagara and the number of interesting applications of electricity which have been developed in this neighborhood through the use of electric power from the Falls.

The technical sessions are being planned by the Meetings and Papers Committee of the Institute, and careful consideration is being given to choosing subjects that will appeal to every member of the Institute. The program will be announced in an early issue of the JOURNAL.

The Convention Committee, the personnel of which was announced in the March JOURNAL, is actively engaged in scheduling excursions and social events which will be prominent features of the convention. There will be visits to various large

electrical plants near the Falls, that will be valuable opportunities to engineers interested in these great power plants. The well established entertainment features are being provided for, such as the tennis matches, golf tournaments, and the baseball game. The entertainment of the visiting ladies will also be a special activity of the committee. All of the afternoons at this convention will be left open for the various social features.

Committee meetings and conferences of Sections Delegates will be held as is usual at the annual convention.

The convention headquarters will be the Clifton hotel, Niagara Falls, Ont.

More detailed information regarding the convention will be published in the May and June issues of the JOURNAL.

Future Section Meetings

Atlanta.—April 27, 1922. Subject: "Modern Dam Construction." Speaker: Mr. R. S. Burroughs, of the Ambersen Construction Company.

Baltimore.—April 21, 1922, Engineers Club, Light and Redwood Streets, Baltimore, 8:15 p. m. Subject: "Wireless Telephony." Speakers: Messrs. E. F. W. Alexanderson, of the General Electric Company, and L. W. Chubb, of the Westinghouse Electric & Manufacturing Company.

Cleveland.—April 18, 1922, Club Rooms of the Electrical League, Hotel Statler, 8:15 p. m. Subject: "Automatic Substations." Speaker: Mr. L. B. Bale, Cleveland Railway Company.

Detroit-Ann Arbor Section.—April 14, 1922, Board of Commerce. Paper by Mr. H. M. Gould, electrical engineer, of the Detroit Street Railways, City of Detroit. This paper will undoubtedly prove of great interest to the public, as the local Railway Company has just announced its willingness to sell its equipment, franchises, etc., to the City of Detroit, and the Mayor is calling a special election April 15. This paper being given the night before election will undoubtedly attract considerable attention.

Erie.—April 18, 1922. Subject: "Electrical Measurements and Meters." Speaker: Mr. C. P. Yoder.

Fort Wayne.—April 20, 1922. Subject: "The Practical Uses of X-Ray." Speaker: Dr. C. C. Grandy, Roentgenologist. Dr. Grandy is a nationally known X-Ray specialist and will present a very interesting paper illustrated by lantern slides.

New York.—A joint meeting of the New York Section of the A. I. E. E. and the Metropolitan Section of the A. S. M. E. will be held in April, probably on the 14th. The subject for the evening has not been definitely decided upon as yet, but notices containing detailed information will be mailed to the membership as soon as possible. This will also be the Annual Meeting of the N. Y. Section of the A. I. E. E. required by the By-Laws of the Section at which the results of the election of officers for 1922-23 will be announced.

Toronto.—April 24, 1922. Annual business meeting and election of officers. Speaker: Professor A. P. Coleman. Subject: "Rocky Mountain Trails to Mount Robson."

Utah.—April 28, 1922, Commercial Club, Salt Lake City, Utah. Subject: "The Manufacture of Dielectric Porcelain." Speaker: Mr. A. M. Jackson, of the Locke Insulator Corporation.

Vancouver.—May 5, 1922, Auditorium, Board of Trade Building, Pender and Homer Streets, Vancouver. Subject: "The A-C. Potentiometer." Speaker: Mr. James Stott.

A. I. E. E. Year Book

The A. I. E. E. 1922 Year Book is available to members without charge, upon application to the secretary, 33 West Thirty-ninth Street, New York, N. Y.

The book contains an alphabetical and geographical catalog of the membership revised to January 1, 1922; also the constitution, by-laws, lists of officers and committees, and much additional information relating to the activities of the Institute.

A. I. E. E. Annual Election

At the meeting of the Board of Directors of the Institute, held in New York, March 17th, the report of the Committee of Tellers, giving the result of its canvass of the nomination ballots received for the offices to be filled at the coming annual election, was presented.

This report included the names of all candidates eligible for election, the names of those who received less than 3 per cent of the total nomination vote having been eliminated, in accordance with the requirements of the Constitution.

The Board resolved itself into a Committee of the whole, and an informal discussion followed, at the close of which the Committee arose and reported its recommendations to the Board. The Board then selected a complete ticket of "Directors Nominees" for the respective offices, in accordance with the provisions of the Constitution. This ticket is as follows:

For President:	Frank B. Jewett, New York, N. Y.
For Vice-Presidents:	District No. 1
	G. Faccioli, Pittsfield, Mass.
	District No. 3
	W. I. Slichter, New York, N. Y.
	District No. 5
	R. F. Schuchardt, Chicago, Ill.
	District No. 7
	H. W. Eales, St. Louis, Mo.
	District No. 9
	H. T. Plumb, Salt Lake City, Utah
For Managers:	H. M. Hobart, Schenectady, N. Y.
	Ernest Lunn, Chicago, Ill.
	G. L. Knight, Brooklyn, N. Y.
For Treasurer:	George A. Hamilton, Elizabeth, N. J.

The election ballots were mailed to the entire membership prior to April 1st, in accordance with the Constitution.

The report of the Committee of Tellers follows:

ABSTRACT OF REPORT OF COMMITTEE OF TELLER ON NOMINATION BALLOTS

March 9, 1922

To the Board of Directors,
American Institute of Electrical Engineers.

Gentlemen:

This Committee has counted and canvassed, in accordance with Article VI of the Constitution, the nomination ballots eceived for officers of the Institute for 1922-1923. The result is as follows:

Total number of envelopes said to contain ballots, received from the Secretary		4206
Rejected on account of bearing no identifying name on outer envelope	66	
Rejected on account of having reached Secretary's office after February 28	125	191
Leaving as valid ballots		4015

These valid ballots were counted and the results is shown below:

FOR PRESIDENT

Frank B. Jewett	2696
Farley Osgood	1287
Scattering and blank	32
	4015

(The scattering vote was divided among ten (10) candidates, each of whom received less than 3 per cent of the total vote.

Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices).

FOR VICE-PRESIDENTS

District		
No. 1. North Eastern		
	G. Faccioli	3034
	Scattering and blank	981
No. 3. New York City		
	W. I. Slichter	3094
	Scattering and blank	921
No. 5. Great Lakes		
	R. F. Schuchardt	1304
	C. I. Hall	1111
	J. C. Parker	1034
	Scattering and blank	566
No. 7. South West		
	H. W. Eales	3084
	Scattering and blank	931
No. 9. North West		
	H. T. Plumb	1675
	G. E. Quinan	1450
	Scattering and blank	890

FOR MANAGERS

H. M. Hobart	2783
Ernest Lunn	2479
G. L. Knight	2132
W. M. McConahey	1536
C. S. McDowell	1201
Scattering and blank	2914

FOR TREASURER

G. A. Hamilton	3115
Scattering and blank	900

(The scattering vote for the various offices was divided among several candidates, each of whom received less than 3 per cent of the total vote.)

Respectfully submitted,

J. B. Bassett, *Chairman*
E. E. Dorting
E. A. Hester
Wm. Hetherington, Jr.
R. R. Kime
S. D. Kutner
W. E. Seaman
Committee of Tellers

A. I. E. E. Directors Meeting

MARCH 17, 1922

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, March 17, 1922, at 3:00 p. m.

Present: President William McClellan, New York; Past-President Calvert Townley, New York; Vice-Presidents W. A. Del Mar, New York, and N. W. Storer, Pittsburgh; Managers E. B. Craft, L. F. Morehouse, W. I. Slichter, New York, F. D. Newbury, Pittsburgh, H. B. Smith, Worcester, Mass; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

Approval by the Finance Committee of monthly bills amounting to $18,325.70 was ratified.

A report was presented of a meeting of the Board of Examiners held March 13, 1922; and the actions taken at that meeting relative to applications for election and transfer were approved. Upon the recommendation of the Board of Examiners, the following action was taken upon pending applications: 132 Students were ordered enrolled; 160 applicants were elected to the grade of Associate; 18 applicants were elected to the grade of Member; 9 applicants were transferred to the grade of Member.

The report of the Tellers Committee of its canvass of the nomination ballots received for the offices to be filled at the 1922 annual election of the Institute, was presented; and the Board selected the "Directors' Nominees" for the respective offices, as listed elsewhere in this issue.

A communication dated February 24, from Local Honorary Secretary Guido Semenza of Italy, was presented, calling attention to the fact that members of the Institute residing in Italy receive the nomination and election ballots too late to participate in the elections. The Secretary stated that he had received other similar complaints from members located in various foreign countries. It was voted that the election procedure be referred to the Law Committee for recommendation to the Board regarding changes in the constitution and by-laws to provide an opportunity for members located in foreign countries to participate in the Institute elections.

In acceptance of an invitation from the Commissioner of Education, Washington, D. C., the President was authorized to appoint delegates to the Second Public Conference on Commercial Engineering Education, to be held at the Carnegie Institute of Technology, Pittsburgh, May 1-2, 1922.

A communication from the Director of the Bureau of Standards was presented, advising that it is intended to carry out the next revision of the National Electrical Safety Code under the Rules of Procedure of the American Engineering Standards Committee and inviting the Institute to designate a representative to serve upon the Sectional Committee which is being organized for this purpose. The President was authorized to appoint a representative upon the Sectional Committee on National Electrical Safety Code.

Past-President Townley, one of the Institute's representatives upon a joint committee of the Founder Societies to consider the advisability of holding an International Engineering Congress in Philadelphia, in 1926, in connection with the Sesquicentennial Celebration, reported upon a meeting of the joint committee held March 16, to the effect that the committee passed a motion recommending that such a congress be held. The Board of Directors adopted the following resolution:

WHEREAS, the Special Joint Committee of the four Founder Societies has recommended holding an International Engineering Congress in Philadelphia in 1926,

RESOLVED: that the American Institute of Electrical Engineers is in sympathy with the recommendation; it recognizes that a successful Congress should receive the moral support and professional participation of the united engineering profession of the United States, suitable cognizance from the Federal Government, and the necessary financial support. As the best method of securing these requisites, the President is hereby authorized—the American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, and the American Society of Civil Engineers concurring—to request American Engineering Council to take the initiative by creating a Joint Committee in which the American Society of Civil Engineers shall be invited to participate and on which they shall have a proportionate representation: this Committee to be authorized to formulate and execute a plan for the organization and conduct of the Engineering Congress; to solicit the participation of other engineering organizations; to secure Governmental cooperation; to devise a financial plan and solicit support therefor. The Committee to have authority to appoint and work with a local subcommittee in Philadelphia—and if necessary with other local committees in other cities, but to have no authority to commit the American Engineering Council or the member or supporting Societies, to any expenditures except such as may be specifically authorized by such Societies, each acting for itself.

In addition to these actions, other matters relating to important activities and the general policy of the Institute were discussed; reference to these matters may be found in this and future issues of the Journal under suitable headings.

Professional Ethics

The A. I. E. E.'s permanent Committee on Code of Principles of Professional Conduct reported to the Board of Directors of the Institute, at a recent meeting, recommending that "to serve as a guide for the membership and for future decisions, the findings of the committee upon cases brought before it be published in the Institute JOURNAL." This recommendation has been approved; and in accordance therewith, attention is called to the following statements covering recommendations made recently by the committee, and which were later approved by the Board of Directors:

1. A member published and circulated privately a document describing apparatus manufactured by the company with which he was connected. This document was copyrighted and included a statement on its title page that it was an abstract of a paper to be presented before the American Institute of Electrical Engineers.

Since no such paper had even been submitted, the unauthorized use of the name of the Institute for advertising purposes was considered by the committee as wholly contrary to our Code of Principles of Professional Conduct, particularly as the Institute would not accept a paper the substance of which had already been published, even if it had not been copyrighted.

The author was therefore severely censured and directed to withdraw the paper from circulation and to notify all to whom copies had been sent, that the statement referring to the A. I. E. E. was unauthorized and incorrect.

2. A member made certain statements in papers filed with the Institute, which statements were believed to be false and were questioned. The matter was referred to the Committee on Code of Principles of Professional Conduct. While the matter was in the hands of this committee the member submitted his resignation. It was recommended that his resignation be accepted.

The Code of Principles of Professional Conduct, which was adopted by the Institute in 1912, is available in pamphlet form; and a copy may be obtained, without charge, by application to the Secretary of the A. I. E. E., 33 West 39th Street, New York.

American Engineering Standards Committee

STANDARDS SUBMITTED FOR APPROVAL

Code for Electricity Meters

The National Electric Light Association and the Association of Edison Illuminating Companies have submitted to the American Engineering Standards Committee for approval as American Standard the code for electricity meters, known as the "Meter Code."

Nine of the ten sections of the present code were prepared in 1912 by a joint committee of the two associations and representatives from the Electrical Testing Laboratories, from the leading meter manufacturing companies and from public service commissions and other regulatory bodies organized for the purpose of supervising electric service. The code contains a tenth section, Part A, B and C of which were brought out in 1916 and Parts D and E in 1920.

The American Engineering Standards Committee would be very glad to learn from those interested of the extent to which they make use of this code and to receive any other information regarding the code in meeting the needs of the industry.

Illuminating Nomenclature and Standards

The Illuminating Engineering Society has submitted to the American Engineering Standards Committee its Nomenclature and Standards Rules, 1918 edition, for approval as American Standard.

The rules were formulated by the I. E. S. Committee on Nomenclature and Standards which has been continuously active since its organization in 1907. Its first report, including matter contained in the present set of rules, was issued in 1910. A second and somewhat amplified report was issued in 1912. This was very similar to the present set of rules. Year by year since that time additions and revisions have been made until the final set of rules was issued in 1918. The committee has adopted certain additions since that time, but they have not yet been put in printed form.

The I. E. S. Committee states that fundamentally the set of illumination units goes back to proposals made by Blondel at the Meeting of the Photometric Commission in Geneva in 1903; that similar proposals in the case of a number of the units were in existence long before that time and that the definitions and rules are in general use in this country and definitions in accordance with these were adopted by the International Commission on Illumination at its meeting in Paris, July, 1921.

The rules may be found in the *Transactions* of the Illuminating Engineering Society, Vol. XIII, No. 9, December 30, 1918. Copies may also be purchased from the American Engineering Standards Committee, 29 West 39th Street, New York City.

The American Engineering Standards Committee would be very glad to learn from those interested of the extent to which they make use of these rules, and to receive any other information regarding them in meeting the needs of the industry.

WORK ACCOMPLISHED DURING 1921

The American Engineering Standards Committee has issued a publication embracing its work during the year 1921. This report outlines the method of work of the committee and gives the list of standards approved during the year, as well as those before the committee at the end of the year; some projects in hand; a list of its publications; and information regarding the various activities of the committee, such as its information service, its government and its international cooperation. Included also are lists of the member-bodies and representatives, of cooperating bodies and of firms providing financial support; of the members and alternates, and the personnel of committees; financial reports; and a copy of the constitution and the rules of procedure.

Information pertaining to the committee's work during the year has been published in various issues of the JOURNAL, and may be found under the committee heading.

CONFERENCE ON CROSSING SPECIFICATIONS

The conference on the question of uniform specifications for crossings of overhead wires, called by the American Engineering Standards Committee at the request of the American Electric Railway Association, was held in New York on March 2, 1922. The question of certain differences of opinion in regard to Part 2 of the National Electrical Safety Code which deals with overhead lines was also disposed of.

The following resolution was passed by unanimous vote:

RESOLVED, that it is the opinion of this Conference that

1. The remaining differences of opinion on Part 2 of the National Electrical Safety Code are small, and the different interests are approaching agreement, and that it is therefore advisable:

2. That the National Electrical Safety Code should be approved by the American Engineering Standards Committee with the understanding that

3. There should immediately be organized a thoroughly representative sectional committee under the procedure of the American Engineering Standards Committee to consider any revisions of Part 2 of the Code which may be deemed necessary by any of the interested parties, and

4. That there should be a set of national specifications for crossings between overhead electric wire lines and railways and between different wire lines, because there is disagreement among existing specifications, and that

5. Such specifications should be prepared by thoroughly representative sub-committees so as to make them in agreement with the Code, with such revisions as may be made under the provisions of paragraph 3 above.

More than 50 representatives were present at the conference, all the principle interests being represented by strong delegations. Much profitable discussion took place, and the status of crossing specifications in various localities was given by representative engineers. Cooperation was emphasized, and the conclusions reached in the above resolution indicate active results.

American Engineering Council

BILL FOR RELIEF OF PATENT OFFICE SIGNED BY PRESIDENT HARDING

On February 18, 1922, President Harding signed the Lampert Patent Office Bill, H. R. 7077. This action marks the end of a long fight waged by the engineering societies through American Engineering Council to obtain from Congress much needed relief from conditions which were rapidly tending to place the Patent office in a state of uselessness.

The passage of this bill which has been advocated by manufacturers, inventors, scientists and lawyers will add $451,000 to the payroll of the Patent Office, increasing the salaries of the examiners approximately 45 per cent and the number of examiners 10 per cent. The bill also contains an amendment which will make a money recovery possible in all patent infringement cases where the patent has been held to be valid and there has been any substantial use of the invention.

This relief has come at a time when the Patent Office is practically a year behind in its work, for there are said to be 65,000 applications pending for patents upon which the first official action has not been taken. However with the checking of the general exodus from the Patent Office ranks it is hoped that new energy will be infused and a situation remedied which threatened American industry and invention.

CHICAGO MEETING, MARCH 10

At the meeting of the Executive Board of the American Engineering Council held in Chicago on March 10, a wide range of topics was considered by the Board. The day was spent in discussion of the numerous subjects that came up for consideration, resulting in definite action being taken in many cases. In the evening the University of Michigan Engineers' Club of Chicago entertained the members of the Board at a dinner, with President Burton of the university and Dean Cooley as the principal speakers. Dean Cooley spoke upon the ideals and purposes of the Federated Societies, expressing the importance of the engineer's participation in public affairs, with the view that the opinion of the engineering profession as a whole is more desirable in great matters of public concern than the opinion of individual engineers.

Business Sessions

The sessions, presided over by President Cooley and the first vice-president, Calvert Townley of New York, were largely attended. The organizing work of the Federation was reported to be proceeding actively. In addition to Dean Cooley's tour, addresses have been made by Secretary Wallace and other members of the Council, including Calvert Townley, Gardner S. Williams and L. P. Alford, before numerous engineering societies in the past three months. The extension of the work of the Publicity Director to the member societies was reported as a growing feature of this branch of the Federation's activities. The report of the executive secretary, L. W. Wallace, presented highly encouraging evidence of the favor with which the idea of engineering federation is being received in this and other countries.

International Federation Considered

The general question of international engineering federation was considered and provoked a discussion in which the constitutionality of a proposal to admit the Engineering Institute of Canada to membership in the Federation, if formal application should be made, was the subject of a lengthy debate. Secretary Wallace reported that the proposal to form an international federation of engineers had been given wide consideration since the address at the January meeting of the Council of Dr. B. Stepanek, the Minister from Czechoslovakia. During the discussion the idea was advanced that the Federation should include engineering organizations "of the American Continent" instead of the United States alone. The Board adopted a proposal to appoint a committee "to consider and report upon the affiliation of other engineering organizations than those within the United States with the F. A. E. S."

National Board of Jurisdictional Awards Upheld

The Board received a report from Rudolph P. Miller of New York, its representative on the National Board of Jurisdictional Awards, stating that the United Brotherhood of Carpenters and Joiners of America have not been observing the decisions of the Jurisdictional Board and that the attitude of the carpenters was causing serious embarrassment to owners, architects, engineers, contractors and workmen in the building industry as well as being detrimental to the public interest. As a consequence of this report, the Executive Board adopted a resolution urging "that the members of the American Institute of Architects and of the F. A. E. S. insert in all specifications and contracts for building operations a stipulation that the decisions of the Jurisdictional Board shall be observed."

It was further decided to enforce this resolution as expeditiously as possible, beginning with those localities in which the trouble appears to be the most acute.

Proposal for Muscle Shoals Investigation Rejected

One of the liveliest discussions of the meeting of the Executive Board arose from a resolution presented by Philip N. Moore of St. Louis that the president of the F. A. E. S. be authorized to offer the Secretary of War the service of a committee of engineers to investigate thoroughly the geological, engineering and manufacturing possibilities of the Muscle Shoals Power Project; the committee to serve without compensation. The resolution was voted down. It was emphasized that further investigation was not as necessary as the impartial selection of facts from the disputed data available.

Great Lakes—St. Lawrence Waterway

The Great Lakes—St. Lawrence Waterway project came before the Board, which decided that at present it was undesirable to take any action. This matter has been under consideration by the Public Affairs Committee of the Council for a considerable period, and the Board's decision was reached after opportunity had been provided for a careful study of the report of the International Joint Commission.

Other Matters Acted Upon

The Board tabled a resolution presented through the Boston Society of Civil Engineers to sanction an amendment to the House Bill creating the Roosevelt-Sequoia National Park, providing that the entire area included within the park should be protected from the intrusion of water power development in the same manner that all existing national parks are protected. The proposal to urge the elimination from the Fordney Bill of the tax on foreign books in English met with a divided report from the Committee on Public Affairs, and following a discussion, in which it was asserted that the proposed duty was a "tax on brains," this resolution was also tabled. Another resolution tabled was on the subject of a national auxiliary language.

Upon the report of the Committee on Employment Service that it believed the maintenance of an employment bureau by the Council to be inadvisable at this time, the Board after discussion, voted to discharge the committee, and instructed the

president to appoint a committee of five to consider the whole question and report to the Board at its next meeting.

The Board adopted appropriate resolutions, presented by Col. A. S. Dwight of New York, on the death of Prof. J. W. Richards of Lehigh University and Col. F. A. Snyder.

Progress Made

Progress reports showed activity on the part of numerous committees. Increased participation in federal matters, through conferences and other close personal contacts with departments and bureaus of Washington, was reported.

A report from E. J. Prindle, chairman of the Patents Committee of the Council, commended the publicity efforts of the Federation as a powerful factor in bringing about the success of the movement to reform conditions in the United States Patent Office. (See notice above). The work of Mr. Prindle was highly praised, and the pen with which President Harding signed the Patent Office Bill, now the prize possession of Mr. Prindle, was passed among the members of the Board as a symbol of effective engineering support of American science and invention.

The Committee on the Elimination of Waste in Industry advised the Board that there continues to be a very great interest on the part of the public in the Waste Report.

Secretary Wallace reported that the membership of the Associated Engineers of Spokane had so increased that the Association was now entitled to a representative on the Council, J. C. Ralston being the appointee. The Engineers Club of Columbus, O., has appointed John R. Withrow as its representative upon the Council.

President Cooley's report gave an encouraging outlook, with much progress made. The financial situation of the F. A. E. S. as reported by the treasurer showed improvement.

Future Meetings

The Committee on Procedure recommended that the next meeting be held in Pittsburgh, the latter part of May, and the following meeting in September or October, in Boston or New York.

National Research Council

MEETING OF DIVISION OF ENGINEERING

The sixteenth meeting of the Division of Engineering of National Research Council was held in New York City on February 14, 1922. In addition to the members of the Division attending, there were present, by invitation, Herman Lemp, of the General Electric Company, Prof. V. Karapetoff of Cornell University, and Col. K. G. Maxwell of the research department, Metropolitan-Vickers Company, Ltd., London, as speakers; Capt. Walter Graham, Scientific Associate, Research Information Service; and the following members of the Advisory Board on Electrical Engineering Reserach: E. B. Craft, E. E. F. Creighton, W. A. Del Mar, Bancroft Gherardi, L. F. Morehouse, and S. S. Wheeler.

The minutes of December 9, 1921, which had been mailed to the members, were approved, without reading. The first part of the evening was then devoted to interesting speeches bearing on the subject of research. Mr. C. E. Skinner, manager of the research department, Westinghouse Electric & Manufacturing Company, and a member of the Division, read an instructive paper on "Selling Research." This was followed by a talk by Prof. Karapetoff, in which he narrated his fifteen years' experience in research, comparing the research spirit in this country with that in Europe. Dr. E. P. Hyde, director of research, National Lamp Works, and a member of the Division, reviewed research from the business viewpoint.

Col. Maxwell gave an interesting account of this, his first visit to our country. He admired our linking in research even concerns which were genuinely competitive in business; such cooperation opening to us great possibilities. He mentioned also the marked advance in appreciation of research occasioned in England by the World War.

Following the speeches, progress reports of various committees were made, as follows:

Progress Reports

Advisory Board on Electrical Engineering Research. Dr. F. B. Jewett, chairman, reported that the Directors of the American Institute of Electrical Engineers had appointed a large advisory board and that a small committee had been selected to develop organization and methods of functioning. This committee has completed its report, and Dr. Jewett promised that it would be presented at the April meeting of the Division.

Committee on Electrical Insulation. Dr. Jewett, chairman, stated that the reason for lack of progress was the business depression. The time is not yet opportune for soliciting even the small funds necessary to carry out successfully the program outlined in the report printed under date of September 20, 1920.

Electrical Core Losses. Professor C. A. Adams, acting chairman in the absence of Professor Kennelly in France, reported that this committee had met during the day and learned of progress made by the members in their individual laboratories. Phenomena accompanying the losses in cores and conductors of electrical machinery are extremely complicated when considered from the standpoint of scientific analysis. Although the principles involved are simple, the engineering methods of computing or predetermining these losses are almost hopelessly crude and superficial. The committee aims to reduce the calculation of core losses as well as of eddy current conductors to a more rational and scientifically exact basis. Progress has been made in the investigations conducted at the four universities which are cooperating. The University of Washington (St. Louis) and the University of Missouri have concentrated their efforts on the measurement of pole-face loss of homo-polar generators. The Massachusetts Institute of Technology is studying the general distribution of flux through air gaps of different types of machines. At Harvard University a study is being made of losses in laminae and analysis of skin-effect at low frequency as a function of thickness. General Electric Company is analyzing core losses in standard induction motors.

Electric Arc Welding. H. M. Hobart, chairman, reviewed the situation, the needs for research, and progress in development of this art since the appointment of the Welding Committee during the war, to aid in ship-building. Prior to that time very little was known in a scientific way—even in the welding of mild steel. Welding of low-carbon steel has reached an advanced stage, although there are still important problems to be solved. Recently the committee has given attention to cast-iron welding problems, which are extremely complex. For more rapid progress there has been appointed as a sub-committee under the chairmanship of Wm. Namack, a group of experts living in the vicinity of Schenectady, and work is being conducted under the auspices of the Northern New York section of the American Welding Society. This regional concentration permits frequent meetings at small expense. Loss of information and interest incident to infrequent meetings is avoided, and enthusiasm kept alive. A summary of the present state of the art will be published shortly. A program of research has been outlined for problems needing further investigation and for gaps in authentic information.

A sub-committee, under the chairmanship of Wm. Spraragen, is dealing with the standardization of electric arc welding apparatus. Its rules in no way interfere with the standardization rules of the American Institute of Electrical Engineers. The report of this sub-committee will be shortly available for publication.

Resistance Welding Committee. H. Lemp, chairman, stated that although this is one of the oldest and most reliable

processes a number of fundamental problems remain to be solved. New applications require fundamental scientific knowledge of the variables that enter into successful resistance welding. Sub-committees have been appointed to formulate plans for standardization of nomenclature, rating of welding transformers, and preparing critical summaries of the art as it exists today.

For this work, the field of resistance welding was divided into five parts: 1, Butt welding, 2, seam welding, 3, spot welding, 4, percussive welding, and 5, direct-resistance method of heating.

Considerable progress has been made on the standardization of welding transformers which will prove equitable to manufacturer, user and central-station man. Standardization is being carried out in close conjunction with the A. I. E. E. standards committee. A critical summary on butt welding will soon be ready for publication. Progress has also been made on the summaries relating to seam, spot, and percussive welding. Mr. Lemp exhibited numerous specimens of resistance welding.

Business of Division

Other business of the meeting included the appointment of Capt. Walter Graham as executive secretary, without salary. Capt. Graham has been appointed a scientific associate of the Research Information Service, Specializing in engineering, to serve as liaison representative between it and the Division, his salary to be paid by the Research Information Service. The chairman recommended appointment as executive secretary to conform to practise established by the Research Council for other divisions.

The appointment of F. W. Davis as second representative of the Society of Automotive Engineers was approved.

It was decided to continue the Committee on Substitute Deoxidizers. Mr. Flinn reviewed the history of this committee. A few steel and ferro-alloy companies have contributed advice or materials, or in some cases, services. The Division has contributed part of the salary of a technical assistant to Dr. Cain. The Bureau of Standards contributed liberally of advice, facilities and incidental services and supplies. All operation and results have been open to all interested persons, and several companies have availed themselves of this information. Results already obtained are of distinct value to manufacturers of deoxidizers and to steelmakers and users; they have been published in several technical journals. Although no funds are available for a time, the Executive Committee approved the recommendation of the Chairman that this committee be continued.

To cope with the marine borers, or shipworms, which are causing great damage in a number of ports of the United States, a national committee has been organized by the Divisions of Engineering and of Biology and Agriculture under the chairmanship of R. T. Betts. Need for action became acute in San Francisco Bay because of destruction amounting to fifteen million dollars during the seasons 1919-1920. The San Francisco port committee has published two valuable reports. Similar port committees are to be organized on other places. Attention will be given to biological engineering and chemical aspects of the problem, including various types of protection for wooden piling and types of construction not subject to attack by the borers. A meeting was held in New York on March 22 under the auspices of the Municipal Engineers of the City of New York, to take definite steps toward the organization of a New York port committee, with the cooperation of railroads, steamship companies, city and state officials, marine insurance companies, U. S. Government engineers, and others.

Since the December meeting, reports have been published on *Steel Ingots*, by Col. W. P. Barba and Dr. Henry M. Howe, and on *Welding Wire Specifications* by that committee of the American Bureau of Welding. Copies may be obtained from the Division office.

The next meeting of the Division will be the annual meeting, on April 21, 1922.

Institute of Radio Engineers

MEETING IN NEW YORK, APRIL 5, 1922

At a meeting of the Institute of Radio Engineers to be held in the Engineering Societies Building, New York City, on April 5 at 8:15 p. m., a paper on the "Resistance and Capacity of Coils at Radio Frequencies," by Professor John H. Morecroft of Columbia University, will be presented. The paper describes theoretically and experimentally the behavior of numerous types of inductances at radio frequencies and contains important design data.

Members of the A. I. E. E. and others interested in the subject are invited to attend the meeting.

Electric Vehicle Show, April 3-15

The electric vehicle show to be held in the showroom of the New York Edison Company, New York City, from April 3 to April 15, 1922, offers an elaborate exhibition, including passenger cars as well as varied styles and sizes of trucks. The vehicles will be displayed during the first week, and the second week will be devoted to demonstrations of methods of handling materials at freight stations and in industrial plants. Accessories will be exhibited both weeks.

Scientific Congress and Technical Exposition

LIEGE, BELGIUM, JUNE-JULY, 1922

On the occasion of the 75th Anniversary of the Foundation of the Association of Graduate Engineers of the School of Liege there will be held in Liege during June and July, 1922, a Scientific Congress and Exposition. All members interested may obtain complete information as to the questions to be considered at this Congress, and terms of subscription, by addressing, Secretary-General, Association des Ingenieurs, Quai des Etats-Unis, 16, Liege.

Report of International Conference on High-Tension Transmission to be Published

An International Conference, organized by the Union des Syndicats de l'Electricité, was held in Paris, from November 21-26, 1921. The object of that Conference was to study all technical questions relative to the construction and operation of long transmission lines operating at very high tension.

Forty-seven delegates representing twelve different countries contributed the results of the personal experience of themselves and of their fellow-countrymen, and, at the same time, presented descriptions of the principal high-tension systems which are in actual operation in France and in other countries, as well as a summary of the legislation relative to such systems.

The Union des Syndicats de l'Electricité is, at present, preparing to publish the report of this Conference in two separate editions, one in French, the other in English.

In order to determine the number of copies to be printed, the Union des Syndicats de l'Electricité requests all those who desire to obtain copies to send word *as soon as possible* how many copies will be wanted, and whether the English or the French edition. The price of each volume is sixty francs for those whose subscription is sent before May first, next. After that date, the price of the volume will be seventy-five francs, or more, depending upon the number of copies available. Subscriptions should be addressed to Mr. Tribot-Laspiére, Secrétaire Général de l'Union des Syndicats de l'Electricité, 25 Boulevard Malesherbes, Paris, France.

PERSONAL MENTION

W. C. Starkey has become vice-president of the Stevenson Gear Company, Indianapolis, Ind. He was previously with The Ohio Brass Company, Mansfield, O.

T. Furuichi, of the Japanese Naval Inspector's Office, Camden, N. J., has been promoted from Lieutenant Commander to Commander, I. J. N.

F. B. Colt, formerly of Brackett & Colt, Inc., is now associated with F. B. Colt & Company, contracting engineers, New York City.

E. C. Rutz has resigned the office of director of public utilities, City of Kalamazoo, Mich., to become superintendent of power and maintenance with the Bryant Paper Company of Kalamazoo.

R. H. McLain has accepted the position of sales manager of The Maine Electric Company, Portland, Me. Mr. McLain is leaving the General Electric Company, where he has been connected with the Schenectady works for a number of years.

B. F. Sunny, president of the Illinois Bell Telephone Company and formerly for nearly fourteen years president of the Chicago Telephone Company, has retired to become chairman of the board of directors of the Illinois company.

Harmon F. Fischer is now associated with Dr. Van H. Manning, director of research, American Petroleum Institute, New York City. He was formerly with the U. S. Bureau of Mines, Washington, D. C.

F. L. Bunker is now connected with the Southern Radio Corporation, Charlotte, N. C., as commercial engineer. He was previously with the Westinghouse Electric & Manufacturing Company in Charlotte.

W. H. R. Dick, who has been in Calcutta, India, with the International General Electric Company, has gone to Rio de Janeiro, Brazil, where he will be with the Brazilian Sales Corporation.

Herbert P. Thomas has resigned his position as chief engineer of Coates & Company, Melbourne, and has accepted appointment as chief engineer to the Southland Electric Power Board, Invercargill, N. Z.

Edward A. Roberts, who for the last five years has been associated with John A. Beeler in his consulting practise in electric railway transportation, New York City, has been appointed chief of the Transit Bureau of the New York Transit Commission.

Major Louis B. Bender, Signal Corps, has recently been transferred from his duty with the Coast Artillery Board at Ft. Monroe, Va., to the Office of The Chief Signal Officer at Washington, where he is now in charge of the Engineering and Research Division of that office.

H. P. Hill, vice-president and general manager of Ophuls, Hill & McCreery, Inc., engineers, New York City, announces that the firm name will be changed to Ophuls, Hills, Inc. Mr. McCreery was not active in the firm, and since the firm contemplates enlarging its scope, a change in name was deemed advisable.

G. J. Newton is with the Dallas Power & Light Company, Dallas, Tex., engaged in designing a complete underground system, part of which will be new, and part remodeled to conform to new conditions. Mr. Newton has had much experience as a designing engineer, specializing on underground distribution systems.

P. A. Lindemann has resigned the position of superintendent of inspections of the Maintenance Company, New York City, and will represent the Hudson & Manhattan Railroad Company at the Berwick, Pa. works of the American Car & Foundry Company, during the building and equipping of its new motor cars.

Arthur G. Gibbony has entered the engineering department of The Ohio Power Company, as superintendent of substations in the Southern Division, and assistant to the electrical engineer, R. R. Krammes, with headquarters at Newark, Ohio. Mr. Gibbony was for several years with Stone-Webster in the middle west, and prior to that time with The Aluminum Company of America.

E. B. Katte, chief engineer, electric traction, New York Central Railroad, has been appointed representative of the American Railway Association on the sectional committee of American Engineering Standards Committee for standardization of symbols for electrical equipment of buildings and ships. The A. I. E. E. is one of the sponsors for this sectional committee. Mr. Katte is a Fellow of the Institute, and has served on various committees.

Paul C. Sorsby, guarantee engineer, turbo electric ship propulsion division of the General Electric Company, has been appointed turbine and generator expert for the International General Electric Company with headquarters at Yokohama, Japan. Mr. Sorsby is a technical graduate and has had fourteen years' extensive engineering experience including twelve years with the General Electric Company. He is a Member of the Institute. He sailed from San Francisco for Japan the latter part of March.

C. E. Skinner, manager of the research department of the Westinghouse Electric & Manufacturing Company, has been appointed assistant director of engineering in that company. His duties as assistant director will cover research, standards and other work along these lines. He will be located in the main engineering offices of the Westinghouse Electric Company at East Pittsburgh, Pa. Mr. Skinner is well-known for his extensive electrical research work, especially on insulation, and his efforts in this direction have had much effect on the development of electrical machine design. He has been with the Westinghouse Company since 1890. He is a Fellow of the A. I. E. E., and is now a member of the Committee representing the Institute on the International Electrotechnical Commission.

S. M. Kintner has been appointed manager of the research department of the Westinghouse Electric & Manufacturing Company, succeeding C. E. Skinner. He will be located in the research laboratory building near East Pittsburgh, Pa. Mr. Kintner joined the Westinghouse Electric & Manufacturing Company in 1903 as an engineer, but left in 1911 to become general manager of the Electrical Signaling Company, which was organized to develop the discoveries and patents of Prof. Fessenden. Mr. Kintner continued with this company through its reorganization into the International Radio Telegraph Company, in 1917, with which company he has been vice-president and president at different times. In September, 1920, he again became associated with the Westinghouse Company.

A. A. Stevenson, the retiring chairman of the American Engineering Standards Committee, has been designated by the committee as a special representative to work with the Department of Commerce in the cooperation between the Department's Division of Simplified Practise and the A. E. S. C. The work of this Division was organized in the latter part of 1921 and is now actively under way. Its purpose is to assist in those reductions of excessive variety and other simplifications which many

industries are undertaking in order to decrease the cost of production and distribution of manufactured articles. Mr. Stevenson is a past-president of the American Society for Testing Materials, and has had extensive experience in standardization work. He is vice-president in charge of manufacture of the Standard Steel Works Company, a subsidiary of the Baldwin Locomotive Works.

Edward B. Craft has been appointed chief engineer of the Western Electric Company, succeeding F. B. Jewett, vice-president of the company, who has been placed in charge of the new telephone department including the engineering, the telephone sales, and the manufacturing departments. Mr. Craft joined the Western Electric Company twenty years ago as a development engineer, and has been granted more than sixty patents on telephone apparatus. In 1917 he became assistant chief engineer in charge of development and design. During the war he served in the consulting engineering division of the Signal Corps, engaged especially in the development of radio telephony for use in the air service; and in the summer of 1918 was sent abroad in behalf of the bureau of steam engineering of the U. S. Navy to act as consulting engineer in connection with radio communication.

John W. Lieb, vice-president of the New York Edison Company, left in March for a three months' trip to Europe. He expects to visit Italy, Switzerland, France, Germany, Holland, and England, but will spend most of the time visiting old friends and business associates in Italy, where he was chief engineer and technical director of the Italian Edison Company from 1882 to 1894. Mr. Lieb will convey the felicitations of the American Institute of Electrical Engineers to its sister society, the Associazione Elettrotecnica Italiana, on the twenty-fifth anniversary of its organization, which it celebrates this year, and while in Rome will also present the certificate of honorary membership in the American Society of Mechanical Engineers which was recently conferred on Gr. Uff Pio Perrone. Mr. Lieb is a past-president of the A. I. E. E., and has also been president of the Association of Edison Illuminating Companies, the Edison Pioneers, the National Electric Light Association, and the New York Electrical Society.

Willis T. Batcheller, consulting engineer of Seattle, Wash., has recently completed a comprehensive report on the Columbia River Pumping and Power Project for the state of Washington, in cooperation with the U. S. Reclamation Service, after six months of investigation. This proposed reclamation project contemplates the irrigation of some two million acres of arid land in central Washington by pumping the water from the Columbia River into the old bed of the river and conducting it to the area to be watered. About one million horse power will be required to drive the motor-driven pumps for raising the water and a generating station will be constructed at the site for furnishing the power. A dam across the Columbia River three thousand feet long will be required to furnish the necessary head on the turbines. In addition to the power required for pumping there will be available some million horse power of continuous energy which can be sold for commercial purposes. This combined irrigation and power project makes a very attractive proposition from the standpoint of the expense of watering the land. General George W. Goethals has completed a personal inspection of the project and is now preparing a reviewing report for the state. Mr. Batcheller is a Member of the A. I. E. E. and served for two years as secretary of the Seattle Section.

Obituary

Roland S. Fend, consulting engineer of Roland S. Fend & Company, Chicago, died on February 18, 1922, following an illness of nearly a year. Mr. Fend was in his 42nd year. Born in Fremont, Ohio, he received his engineering education in a special course at the Cleveland Y. M. C. A. under tutors from the Case School of Applied Science, at the same time working with the Elwell Parker Electric Company. In 1902 he was placed in charge of direct-current generators and motors for this company. Three years later he left to accept the position of superintendent of the electric automobile department of the Columbus Buggy Company, in charge of the design and manufacture of all electric cars made by this company. In 1909 he became chief engineer of the Woods Motor Vehicle Company, Chicago, where he remained until 1917, when he opened his own office in Chicago as consulting engineer. Mr. Fend became a Member of the Institute in 1916.

George V. Wendell of the department of physics of Columbia University died at his home in New York City on March 15, 1922. Professor Wendell was well-known to a great many engineers through his work in teaching for twenty-eight years at Massachusetts Institute of Technology, Stevens Institute and Columbia University. Born in Plainfield, N. J., in 1871, he was graduated from Massachusetts Institute of Technology in 1892, and continued his studies in Berlin and Leipzig where he received the degrees of A. M. and Ph. D. Dr. Wendell then taught physics for fifteen years at M. I. T., after which he went to Stevens Institute for two years. During the last eleven years he has had charge of the teaching of physics to all the engineering students at Columbia University and was very enthusiastic in developing the new six-year course in engineering at that institution. Dr. Wendell was a member of the American Physical Society and prominent in its activities.

Lingan Strother Randolph, consulting engineer and professor of mechanical engineering at the Virginia Polytechnic Institute for twenty-five years, died recently at his home in Baltimore. Prof. Randolph was born in Martinsburg, W. Va., in 1860, and was graduated from the Stevens Institute of Technology in 1883. During the next ten years he held electrical engineering positions, including superintending the installation of an electric light plant in the shops of the Cumberland and Pennsylvania Railway at Mt. Bavage, Md., and designing and patenting a new form of electrolytic vat while with the Baltimore Electrical Refining Company. In 1893 he became professor of mechanical engineering at Virginia Polytechnic Institute, remaining there until 1918, when he joined the Emergency Fleet Corporation at Philadelphia. He had made his home in Baltimore since December, 1919. During his years of service in the teaching profession Prof. Randolph kept up his active work as consulting electrical and mechanical engineer, and was in charge of the design and construction of a number of lighting and power plants. He held membership in both the American Society of Civil Engineers and the American Society of Mechanical Engineers, and was a Fellow of the American Institute of Electrical Engineers, which he joined in 1893.

Wm. F. Doherty's Slayers Convicted

It may be of interest to some of our members to learn that the murder of Wm. F. Doherty in Bombay by Indian rioters on November 19 last has been thoroughly investigated by government authorities in India. Eight of the rioters were tried in high court for the murder, and of these eight, two were sentenced to death, four to imprisonment for life, one to imprisonment for two years, and the other discharged. Notice of Mr. Doherty's death was published in the February issue of the Journal. He was part owner of the Bombay Building Supply Company, and had been a member of the Institute for several years.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

LICENSE LAWS FOR ENGINEERS

The acts regulating the practise of engineering in the following states are now on file in the Engineering Societies Library:

State	In effect	State	In effect
Arizona	Mar. 9, 1921	New Jersey	Apr. 20, 1920
Colorado	Apr. 5, 1921	New York	May 5, 1921
Florida	Apr. 30, 1921	North Carolina	Feb. 25, 1921
Idaho	1921	Oregon	May 25, 1921
Illinois	Mar. 10, 1921	Pennsylvania	May 25, 1921
Indiana	Mar. 10, 1921	Tennessee	Apr. 9, 1921
Louisiana	July 8, 1920	Virginia	May 4, 1920
Minnesota	Apr. 25, 1921	Wyoming	1919

The scope of the different laws and comparisons of their provisions with the uniform law recommended by Engineering Council are summarized in these references:

Am. Soc. C. E. Proceedings.

- Recommended uniform registration law. January, 1920, p. 32.
- Abstracts of existing engineers license laws. October, 1920, p. 767.
- Council approves uniform registration law as revised. November, 1920, p. 850.
- Recent laws for the registration of engineers. May, 1921, p. 518.

Mining and Metallurgy.

- Registration of engineers, by B. B. Gottberger. November, 1921, p. 15.

TRANSACTIONS OF THE INTERNATIONAL ENGINEERING CONGRESS, 1915

The transactions of the International Engineering Congress which was held in San Francisco simultaneously with the Exposition celebrating the opening of the Panama Canal are now available through the Engineering Societies Library. These papers form a valuable contribution to any collection of modern engineering literature, since the congress, in scope and character, was truly international.

The entire set consists of eleven bound volumes accompanied by an index volume giving an historical and statistical account of the congress, abstracts of all the papers presented and a very usable table of contents and author index. With the exception of the volume on the Panama Canal the treatment given each subject has been in the nature of a broad survey with some special reference to important lines of engineering advance. The papers are accompanied by a bibliography of the literature of each subject so that the reader can extend his research into any one of the topics treated.

Only a few complete sets are left but the library has a large number of some of the individual volumes and papers which it will gladly supply to those who wish to purchase them.

BOOK NOTICES (FEB. 1-28, 1922)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

HYDROELECTRICAL ENGINEERING.

By Richard Muller. New York, G. E. Stechert & Co. 1921. 431 pp., diagrs., 10 x 7 in., cloth. $6.00.

Contents:—Hydrology.—Stream meeasurements.—Canals.—Pressure Pipes.—Dams.—Turbines.—Power house and substation equipment.—Transmission lines.—Investigation of water power projects; Economics.—Description of hydroelectric plants; Evaluation of water powers; Legislation.

A systematic exposition of those principles of hydraulic and electrical engineering which underly the design of hyroelectric plants. Intended for engineers engaged in designing and constructing plants or reporting on their commercial possibilities.

MANAGEMENT OF ACCUMULATORS.

By Sir David Salomons. Ninth edition. Lond. and N. Y., Sir Isaac Pitman & Sons Ltd., 178 pp., illus., 7 x 5 in., cloth. $3.00.

Earlier editions have appeared as the first volume of "Electric Light Installations and the Management of Accumulators." This edition, which is largely rewritten, gives a general survey of the construction, management and use of storage batteries, adapted to use by owners and users. Particular attention is given to the technique of charging and discharging, and to failures.

PRINCIPLES OF ALTERNATING CURRENTS.

By Ralph R. Lawrence. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. (Electrical engineering texts.) 432 pp., 8 x 6 in., cloth. $4.00.

A text-book developed from notes on alternating currents used for several years at the Massachusetts Institute of Technology with the junior students in electrical engineering.

RAYS OF POSITIVE ELECTRICITY, AND THEIR APPLICATION TO CHEMICAL ANALYSES.

By Sir J. J. Thomson. Second edition. Lond. and N. Y., Longmans, Green and Co., 1921. (Monographs on physics.) 234 pp., illus., plates, 9 x 6 in., cloth. $5.25.

This work gives an account of the experiments on positive rays which have been made at the Cavendish Laboratory, together with accounts of researches on the Doppler effect in positive rays and on anode rays. Special attention is given in this new edition to those properties of positive rays which seem to throw light on the structure of molecules and atoms and on chemical combination. This edition contains a considerable amount of new matter, both text and plates.

INGENIEUR-MATHEMATIK.

By Heinz Egerer. Bd. 2. Berlin, Julius Springer, 1922. 713 pp., 9 x 6 in., cloth. 528 M.

The author of this work has endeavored to present the subject in a manner that will give the engineer a thorough grounding in those branches which he will find useful in his work, and to enable him to think and feel mathematically in later years, when most mathematical formulas are forgotten.

Volume one, upon algebra, analysis, etc., appeared several years ago. The present volume treats of differential integral calculus, series, curves, maxima, and minima. A third volume is in preparation.

Etude Geometrique des Transformations Birationnelles et des Courbes Planes

By Henri Malet. Paris, Gauthier-Villars et Cie, 1921. 259 pp., diagrs, 10 x 7 in., paper. 32 fr.

A study, by synthetic methods of birational transformations and plane curves. It strives particularly to establish the first principles and to set forth precisely in logical and geometrical fashion, the conditions under which the homographic correspondence of laws is based. The author's exposition of modern geometry is based on the methods of Chasles and Poncelet.

Burning Liquid Fuel.

By William Newton Best. (Revised edition.) N. Y., U. P. C. Book Co., Inc., 1922. 341 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

This revised and enlarged edition of Dr. Best's book formerly entitled the "Science of Burning Lquid Fuel," is a plain straightforward summary of long practical experience in designing and erecting oil fuel installations. Specific information is given upon the use of liquid fuel in many industries and upon all the various forms of equipment. Drawings show how the equipment is applied to various purposes. The book discusses, among other topics, locomotive, stationary, marine and low pressure boiler equipment; practise in foundries and forge shops; and equipment for the sugar, copper, ceramic, cement, baking, candy and oil industries.

The Foreman and His Job.

By Charles R. Allen. Phila. and Lond., J. B. Lippincott Co. 1922. 526 pp., 8 x 5 in., cloth. $3.50.

This book has grown from the experience of the author in organizing and conducting conferences of foremen, called to discuss matters that affect the efficiency of their work. The matter here presented deals with the problems that confront the foreman and suggests proper ways to deal with them. The book is intended for foremen and other minor executives and also for organizers of foremen's conferences, who will find it a suggestive guide in arranging programs.

Introduction to the Theory of Relativity.

By L. Bolton. N. Y., E. P. Dutton and Co., 1921. 177 pp., 8 x 5 in., cloth. $2.00.

This is to a large extent, Mr. Bolton's essay on Relativity and Gravitation, which won the Eugene Higgins prize, extended to some twelve times its length. The book forms a simple introduction to the new general theory of mathematical physics, showing that this develops easily and naturally out of the search for a general mode of statement of physical laws. The author has bent his efforts specially to making the reader understand the general drift of the principle of relativity, to realize what it is all about.

La Theorie de la Relativite et ses Applications a L'Astronomie.

By Emile Picard. Paris, Gauthier-Villars et Cie, 1922. 27 pp. paper.

In this little book the Permanent Secretary of the Academie des Sciences gives an interesting historical and critical sketch of the theory of relativity with reference to its astronomical applications.

Past Section and Branch Meetings

PAST SECTION MEETINGS

Akron.—February 22, 1922. Paper: "The Psychology of Success." Author: Mr. J. W. Bankes, Dean of Teachers' College, Municipal University of Akron. Attendance 15.

Atlanta.—February 23, 1922, Chamber of Commerce Building. Subject: "Electrification of Bloom Mills." Speaker: Mr. S. N. Roberts, of the Atlantic Steel Company. The talk was illustrated by interesting charts and lantern slides. Attendance 60.

Baltimore.—February 17, 1922, Engineers Club. Subject: "Design and Construction of the New Hell Gate Station." Speaker: Mr. H. W. Leitch, Superintendent of Power Plants, United Electric Light and Power Company, New York. After the meeting refreshments were served. Attendance 80.

Boston.—February 15, 1922, Lorimer Hall, Tremont Temple. Joint meeting of the Boston Sections of the A. I. E. E. and A. S. M. E. and Boston Society of Civil Engineers. Paper: "Coordination of All Transportation Mediums—Railways, Waterways, Motor Truck Transportation, Traction Lines—by the Use of the Unit Container System." Author: Mr. Benjamin Franklin Fitch, of the Motor Terminals Company, New York. Attendance 300.

February 28, 1922, Lorimer Hall, Tremont Temple. Joint meeting of the Boston Sections of the A. I. E. E. and A. S. M. E. and the Boston Society of Civil Engineers, and practically a continuation of the meeting held on February 15, 1922. Paper "Problems Due to the Growth of Motor Transportation." Author: John M. Cole, Commissioner of Public Works of the Commonwealth of Massachusetts. Professor W. K. Hatt, Director of Highway Research, under the auspices of the National Research Council, opened the discussion with a talk upon the necessity of research in motor transportation, and illustrated his points with lantern slides. Attendance 300.

Chicago.—February 27, 1922, Rooms of Western Society of Engineers. Joint meeting of the Chicago Section A. I. E. E. and the Western Society of Engineers. Professor Charles F. Scott, Sheffield Scientific School, Yale University, gave an enlightening talk on the general subject of the relation that engineering has held to the development of the useful arts, and the responsibility of the engineer in view of the present highly advanced state of those arts. Mr. Paul E. Holp talked on the use of moving pictures for visual education. Attendance 200.

Cleveland.—January 18, 1922, Electrical League Rooms. Subject: "Refrigeration." Speaker: Mr. A. C. Bishop. Attendance 67.

February 21, 1922, Electrical League Rooms. Subject: "Steam Engineering Practise in Modern Central Stations." Speaker: Mr. T. E. Keating, General Engineer, Westinghouse Elec. & Mfg. Company. Attendance 61.

Denver.—February 25, 1922, Adams Hotel. The meeting was preceded by the usual dinner. Subject: "Radium" (illustrated by lantern slides and demonstrations). Speaker: Mr. C. W. Whittemore, Chief Physicist of the Radium Company of Colorado. Attendance 25.

Detroit-Ann Arbor.—January 25, 1922, Natural Science Building, University of Michigan. Subject: "The Relation of the Electrical Engineers to Fire Prevention and Fire Protection." Speaker: Mr. R. G. Loughead, Chief Engineer of the Michigan Inspection Bureau. Moving pictures showed the ways in which fires were caused and the means taken to extinguish them. Attendance 110.

February 10, 1922, Detroit-Edison Company Service Building. An extremely interesting paper was presented by Mr. Wirt F. Scott, Manager of Industrial Heating Section of the Westinghouse Electric & Manufacturing Company, Mansfield, O. Mr. Scott devoted most of the paper to the electric steel treating furnaces and to electrical enameling, showing many pictures on the screen illustrating the apparatus and its application. Professor Hirschfeldt, of the Detroit Edison Company, added materially to the interest of the paper by his discussion of the same. Attendance 65.

Erie.—January 17, 1922, Academy High School. "Radio Telephone Reception." A public demonstration was given of radio transmission and reception. Attendance 775.

February 21, 1922, Board of Commerce Rooms. Symposium on practical safety in electrical construction, arranged by Mr. M. C. Goodspeed, Safety Engineer, General Electric Company: "Safety Precautions in Use of Meters" by Mr. Fay Catlin; "Oil Switches in Power Stations" by Mr. A. O. Foote; "Operation of High-Tension Power Lines" by Mr. F. A. Tennant. The talks were followed by films showing safeguards used in manufacturing G. E. lamp sockets. Attendance 50.

Fort Wayne.—February 16, 1922. Subject: "The History and Future of Niagara." Speaker: Mr. Frank B. Taylor, Geologist. The talk was illustrated by lantern slides showing geologic formations and peculiar characteristics of the river and falls, which brought out interesting facts about the gorges and their formation. In conclusion, the speaker showed the wonderful possibilities of the power development which have only been partially realized in installations now made, particularly regarding the available head which could be utilized. The talk was concluded by a motion picture of the falls which showed many interesting points in detail. Refreshments were served. Attendance 80.

Indianapolis-Lafayette.—February 24, 1922. Subject: "Measuring Gas Electrically." Speaker: Mr. R. H. Kruse, Thomas Meter Department, The Cutler-Hammer Mfg. Company, Milwaukee. The talk was illustrated by slides. Attendance 50.

March 4, 1922. Subject: "Leather Belt Making." Speaker: Mr. A. Beals, of Charles A. Schieren Company, New York. The speaker presented a motion picture showing the process of leather belt making from the hide to the finished product. Attendance 61.

Ithaca.—January 20, 1922, Franklin Hall, Cornell University. Subject: "Radio Telegraphy." Speaker: Mr. Ralph Bown, of the American Telephone & Telegraph Company. Attendance 200.

Los Angeles.—February 13, 1922, Assembly Room, Edison Building. The meeting was preceded by a dinner at Jahnkes Tavern in honor of the speaker. Subject: "The Human Voice and Its Electrical Transmission." Speaker: Mr. John Mills of the Western Electric Company, New York. The talk was illustrated by moving pictures and demonstrations were made of some of the scientific features. Attendance 300.

Lynn.—March 1, 1922. Subject: "The Work of the Bureau of Standards." Speaker: Dr. S. W. Stratton, Director of the U. S. Bureau of Standards, Washington, D. C. The lecture was illustrated by lantern slides showing various phases of the work at the Bureau. Attendance 225.

Milwaukee.—February 15, 1922, Milwaukee Athletic Club. Meeting of the Engineers Society of Milwaukee, under the auspices of the Milwaukee Section A. S. M. E. Subject: "Modern Unaflow Steam Engine Practise." Speaker: Mr. Robert Cramer, Consulting Engineer. Attendance 120.

Minnesota.—February 27, 1922, University of Minnesota. Subject: "Inductive Interference Between Electric Power Lines and Telephone Lines.' Speakers: Messrs. H. L. Gray, of the Northwestern Bell Telephone Company, Omaha, Neb., and T. D. Crocker, of the Northern States Power Company, Minneapolis, Minn. Attendance 110.

New York.—On the evening of Wednesday, March 15, 1922 a joint Section Meeting of the Metropolitan Sections of the A. I. E. E., A. S. M. E., A. I. M. E., and A. S. C. E. was held in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York. An audience of about 900 filled the room to capacity. Nelson P. Lewis, Chairman of the New York Section of the A. S. C. E., presided and after calling attention to the intense interest of New Yorkers on the subject of the evening, introduced the first speaker, E. H. Outerbridge, Chairman of the Port of New York Authority. Mr. Outerbridge outlined what the Port Authority consisted of, how it was established and what it is hoped to accomplish. The next speaker was the Chief Engineer of the Port of New York Authority, Mr. B. F. Cresson, Jr. Mr. Cresson explained what had been accomplished in Liverpool, England under a similar commission and also explained specific plans laid out by the Authority for solving the problem of freight distribution in New York, particularly the plans for marginal railways and an automatic electric railway operating eight car trains on a loop system. Mr. Morris Sherrerd, consulting engineer of Newark, N. J., then presented the problem from New Jersey's viewpoint. A moving picture of the Port Authority district was then shown, including a reel outlining the various steps at present necessary in the handling of potato shipments from arrival in the terminal yards in New Jersey, down to the consumer, including the costs of each opertion per 100 lb.

Philadelphia—February 13, 1922, The Engineers Club. Subject: "The Industrial Substation—Its Design and Construction." Speaker: Mr. Richard H. Silbert, of the Philadelphia Electric Company. Attendance 88.

Pittsfield.—February 9, 1922, G. E. Auditorium. Subject: "Relativity." Speaker: Dr. Charles P. Steinmetz. Fourth and last lecture on this subject by Dr. Steinmetz. Attendance 150.

February 24, 1922, Park Club. Subject: "The Rare Gases—Their History, Properties and Uses" (illustrated by lantern slides and experiments). Speaker: Dr. R. B. Moore, Chief Chemist of the Bureau of Mines, Washington, D. C. Attendance 150.

March 9, 1922, Y. M. C. A. Subject: "The Geologic History of Mount Greylock." Speaker: Professor T. Nelson Dale. The talk was illustrated by lantern slides. Attendance 350.

Providence.—March 7, 1922, Providence Engineering Society Rooms. Paper: "The Sperry Gyroscope." Author: Mr. Robert B. Lea, of the Sperry Gyroscope Company, Brooklyn, N. Y. This was a joint meeting of the Providence Section A. I. E. E. and the Power Section of the Providence Engineering Society. Attendance 75.

Rochester.—February 24, 1922, Powers Hotel. Subject: "The Manufacture of Underground Cables." Speaker: Mr. W. C. Hayman, of the General Electric Company. The lecture was very well illustrated by slides showing the wire drawing, cabling, manufacture and preparation of rubber insulators for cables and lead covered cable manufacture. Two moving picture films were also greatly enjoyed. Attendance 45.

St. Louis.—February 22, 1922, Engineers Club. The meeting was given over to the Associated Engineering Societies. Subject: "Street Lighting." Speaker: Mr. P. Y. Danley, of the Westinghouse Electric & Manufacturing Company. Slides were shown illustrating lighting practises of today and of the past. Attendance 45.

San Francisco.—February 8, 1922, Native Sons' Hall. Subject: "The Electrical Transmission of the Human Voice." Speaker: Mr. John Mills, of the Western Electric Company. With the aid of moving pictures and lantern slides the speaker presented a most interesting talk on the transmission of the human voice by electricity. Attendance 350.

February 24, 1922, Engineers Club. Subject: "Proposed Hydroelectric Power Bill." Speaker: Mr. Eustace Cullinan. Attendance 40.

Schenectady.—February 17, 1922, Edison Club Hall. Subject: "Construction of the Caribou Hydroelectric Power Plant." Speaker: Mr. Albert A. Northrop, of Stone & Webster, Inc. Moving pictures and lantern slides aided in presenting the description of this 60,000-horse power installation. Attendance 150.

March 3, 1922, Edison Club Hall. Joint meeting of the Schenectady Section A. I. E. E., Society of Engineers of Eastern New York, and Eastern New York Sections of the American Society of Mechanical Engineers and American Chemical

Society. Subjects: "The Neglected Half" by Mr. A. Thornton Lewis, of the York Heating and Ventilating Corporation; "Experiment Station of the American Society of Heating and Ventilating Engineers" by Professor Anderson. Attendance 125.

Seattle.—February 15, 1922, Engineers Club. Subject: "Electricity in the Lumber Industries." Speaker: Mr. E. F. Whitney, of Portland, Ore. A moving picture film entitled "The Conquest of the Forest" was shown to illustrate the various operations described during the evening. Attendance 215.

Spokane.—February 24, 1922, Davenport Hotel. Joint meeting with local Section A. S. M. E. Subject: "Compounding the Diesel Engine." Speaker: H. V. Carpenter, Dean of Engineering, State College of Washington. Attendance 30.

Toronto.—February 10, 1922, Toronto University. Subject: "The Installation of Power Plant Equipment." Speaker: Mr. F. H. Farmer, of the Canadian Westinghouse Company. Attendance 160.

February 28, 1922, Toronto University. Joint meeting with Ontario Section A. S. M. E. Subject: "Industrial Electric Oven and Furnace Construction and Application." Speaker: Mr. J. L. McK. Yardley. Attendance 75.

Urbana.—February 23, 1922. Subject: "The Human Voice, Its Electrical Transmission." Speaker: Mr. John Mills. Attendance 150.

Utah.—February 24, 1922, Gold Room, Commercial Club. Subject: "Wireless on Wire Lines." Speaker: Mr. C. C. Pratt, of the Mountain States Telephone & Telegraph Company. The paper was illustrated by numerous diagrams to show the physical and operating characteristics of the transcontinental circuits as now operated by the American Telephone & Telegraph Company. Following the paper there was an inspection trip through the Mountain States Telephone & Telegraph Company's plant to illustrate the subject of the paper. Attendance 110.

Washington.—February 14, 1922, Cosmos Hall. Subject: "Bringing the Central Office to you." Speaker: Mr. Gascoigme, of the Chesapeake & Potomac Telephone Company. Sections of a telephone switchboard as used in a central office were actually operated by regular central office operators, who addressed the members and explained the "Whys" and "Hows" of everyday service. Moving pictures, "Close-Ups" of telephone construction and operation were also shown. Attendance 150.

Worcester.—February 16, 1922, E. E. Building of W. P. I. Subject: "Telephone Transmission Between Cuba and Catalina." Speaker: Dr. Harold S. Osborne, of the American Telephone & Telegraph Company, New York. The talk was illustrated with stereopticon slides. Attendance 52.

PAST BRANCH MEETINGS

Alabama Polytechnic Institute.—March 9, 1922. Professor Hill delivered a lecture on "Railway Electrification," furnished by the Westinghouse and General Electric Companies, and illustrated by slides. Attendance 21.

University of Arizona.—February 16, 1922. Subject: "Westinghouse, The Institution" (illustrated by slides). Speaker: Mr. Willson. Attendance 22.

February 23, 1922. Subject: "The Phenomena of Lightning." Speaker: Professor Cloke. Attendance 27.

University of Arkansas.—February 14, 1922. Subjects: "Compounding of Diesel Engines" (discussion from article), by Mr. Loid Dill; "Wireless Telegraphy Developments" by Mr. R. H. Joerden. The society was given a concert by wireless from the Westinghouse station at Pittsburgh. Attendance 11.

February 28, 1922. Subjects: "Elementary Theory of Wireless Telephony" by Professor W. L. Teague; "Discussion of Westinghouse Graduate Course" by Professor H. W. McKinley. Attendance 15.

Armour Institute of Technology.—February 17, 1922. Subject: "Automatic Telephone" (miniature set for demonstration). Speaker: Mr. H. Love. Attendance 48.

California Institute of Technology.—February 16, 1922. Subject: "Development Program of the Southern California Edison Company." Speaker: Mr. H. A. Barre, of the Southern California Edison Company, Los Angeles. Attendance 20.

University of California.—March 8, 1922. Subject: "Large Alternating-Current Alternators." Speaker: Mr. A. G. Jones, Secretary of the San Francisco Section of the A. I. E. E. The construction of alternators was illustrated by slides. Attendance 26.

Carnegie Institute of Technology.—February 23, 1922. Subject: "Changing from Overhead to Underground Electrical Distribution Systems in the City of Baltimore." Speaker: Mr. G. E. A. Fairley, Superintendent of Grounds and Buildings, Carnegie Institute of Technology. Attendance 45.

Colorado Agricultural College.—February 20, 1922. Subject: "The Electron Theory." Speaker: Professor L. S. Ward. Attendance 13.

University of Colorado.—February 16, 1922. Subject: "Service Problems." Speaker: Mr. McCallam, of the Westinghouse Electric & Manufacturing Company. Attendance 33.

Drexel Institute.—March 1, 1922. Subject: "Construction of Synchronous Motors." Speaker: Professor E. O. Lang.

Iowa State College.—February 15, 1922. Subjects: "X-Rays" by Mr. O. E. Raffensperger, E. E. '22; "Electrical Porcelain" by Mr. A. F. Kenyon, E. E. '22; "Value of Membership in A. I. E. E." by Professor Kurtz. The following films, furnished by courtesy of the General Electric Company, were shown: One-reel "Revelations"; one-reel "The Potter's Wheel"; one-reel "Beyond the Microscope"; two-reels "Fairy Magic." Attendance 100.

State University of Iowa.—January 4, 1922. Subject: "Transmission of Owen Magnetic Motor Car." Speaker: Mr. W. D. Crozier. A two-reel moving picture on "The Starting and Lighting System (Northeast) Used on the Dodge Bros. Motor Car" was shown. Attendance 28.

January 18, 1922. Election of officers as follows: Chairman, Edwin Paintin; Vice-Chairman, R. V. Morse; Secretary-Treasurer, P. F. Bowman. Attendance 28.

February 1, 1922. Joint meeting. Subject: "Blowers in Connection with Paper Making." Speaker: Mr. C. W. Rogers, of the New York Blower Company. Attendance 26.

February 8, 1922. Subjects: "Transmission of Human Voice Across the Continent," by E. R. Mead; "Ornamental Street Lighting" by T. L. McDaniel; "Recent Hydroelectric Development, Namely, The Power Plant at Beldon California," by J. Moran. Attendance 29.

March 1, 1922. Subjects: "The Electric Furnace," by A. R. Oakleaf; "Electric Railway Progress," by Roy Mathews; "Transmission and Transformers at Pitts River Project," by W. E. Nelson; "Student Branch A. I. E. E.," by Professor Ford. Attendance 36.

March 8, 1922. Educational moving picture on "The Spirit of Progress," from The Acme Manufacturing Company. Attendance 35.

Kansas State College.—February 27, 1922. Subjects: "Advertising" by T. J. Manry '22; "Salesmanship" by J. J. Seright '22; "Some Electric Railway Systems in the United States" by Asa Ford '22. Attendance 60.

University of Kansas.—February 9, 1922. Subjects: "The Graduate Student in Large Industry" by C. E. Lynn '18; "Logging in California" by E. Philleo; discussion by Professor Shaad on the free current generating apparatus recently invented. Attendance 40.

February 23, 1922. Entire meeting given over to arousing interest in the Electricals' Banquet and Engineers' Day. The

Electricals' Orchestra and Quartette furnished entertainment for the evening. Attendance 55.

Lehigh University.—March 10, 1922. Subjects: "Experiences in Power Plant Work" by H. H. Marsh, Jr. '22; "Industrial Motor Control" by W. E. Harrison, Westinghouse Electric & Manufacturing Company, Philadelphia, Pa. Attendance 30.

University of Maine.—March 1, 1922. Subjects: "Single Track Railways" by Mr. Creamer of the Faculty; "Electric Ship Propulsion" by Harry L. Jackson (Student). Attendance 22.

University of Michigan.—March 8, 1922. Subject: "Scientific Shop Management" (illustrated). Speaker: Mr. A. P. Ball, of the Square D Switch Company. Attendance 35.

University of Nebraska.—February 15, 1922. Subjects: "The History of Radio" by Mr. T. J. Woth; "The Use of the Thermionic Tube in Radio Telephone Communication" by Mr. H. J. Heim. A demonstration was given of radio telephone receiving, amplifying so that it could be heard all over the room. Attendance 34.

University of North Carolina.—February 16, 1922. Smoker. Speaker: Dr. Collier Cobb, of the Geology Department of the University. Subject: "Hydroelectric Development in Japan." Attendance 40.

March 2, 1922. The following moving pictures were shown: "The Electrical Giant" and "That Fairy in the Snow Flake." Attendance 225.

University of North Dakota.—February 13, 1922. Program based on life and achievements of Thomas A. Edison. Short talk by Mr. Hough on the work of Mr. Edison. The following moving pictures were shown: "The Glow of the Lamp" and "The Benefactor." Attendance 40.

University of Notre Dame.—February 27, 1922. Reports were read of the inspection trip through the South Bend Power Plant on February 25. Attendance 15.

Ohio State University.—February 24, 1922. Subject: "A Review of Electrical Engineering Developments and Causes." Speaker: Mr. B. G. Lamme, Chief Engineer of the Westinghouse Electric & Manufacturing Company, E. Pittsburgh, Pa. Attendance 300.

March 2, 1922. "Freshman Party." Talk by Professor Caldwell. Electrical stunts in the laboratory. Radio concert. Refreshments. Attendance 150.

March 8, 1922. Election of officers as follows: Chairman, W. M. Kellogg; Vice-Chairman, R. A. Reardon; Secretary-Treasurer, Orris McGinnis. Talk on "Summer Employment" by R. M. Boyer. Attendance 50.

University of Oklahoma.—February 15, 1922. Talks on the plants and factories of the Mid-Western industrial and power centers, by members of Senior Electrical Inspection Party. Attendance 29.

Oregon State College.—February 1, 1922. Subject: "The Vacuum Tube as a Generator, a Modulator, and an Amplifier." Speaker: Mr. Mills, of the Western Electric Company. Attendance 160.

Pennsylvania State College.—March 2, 1922. Subject: "Automatic Street Car Controls: General Electric and Westinghouse Types." Speaker: Dr. E. C. Woodruff, of the Pennsylvania State College. Attendance 54.

University of Pittsburgh.—February 15, 1922. Subjects: "How the Westinghouse Conducts Its Radio Broadcasting" by Mr. W. A. Raring; "Magnetic Control" by Mr. Craig. Attendance 39.

March 1, 1922. Subjects: "Resuscitation" by Mr. R. P. Marshall; "Testing of Street Car Motors by the Pittsburgh Railways Company" by Mr. A. J. Marshall. Attendance 40.

Purdue University.—January 31, 1922. Subject: "The Design of Transformers" (illustrated by slides from the G. E. Co.). Speaker: Mr. J. B. Bailey, of Purdue University. Attendance 59.

February 14, 1922. Subject: "The Application of Electric Motors to Ventilating Machinery" (illustrated by large drawings). Speaker: Mr. A. G. Sutclift, of the Ilg Ventilating Company. Attendance 70.

February 24, 1922. Subject: "Voice Transmission" (illustrated by three reels of Western Electric film and oscillograph projections of voice waves). Speaker: Mr. John Mills, of the Western Electric Company. Attendance 204.

February 28, 1922. Subject: "The Manufacture of Paper" (illustrated by lantern slides). Speaker: Professor J. D. Hoffman. Attendance 103.

Rensselaer Polytechnic Institute.—February 14, 1922. Papers read: "History and Application of Pyrometry to Industry" by Dr. F. M. Sebast; "Expansion and Radiation Pyrometers" by Mr. P. T. Slattery; "Thermocouple Pyrometers" by Mr. A. R. Hogben; "Optical and Radiation Pyrometers" by Mr. G. F. J. Tyne; "Pyrometers in Modern Central Stations" by Dr. W. L. Robb. Attendance 91.

Rose Polytechnic Institute.—February 23, 1922. First lecture of a series on "The Electron Tube and Its Applications to Radio Telegraphy and Telephony" by Professor F. M. Stone. Attendance 35.

March 2, 1922. Informal talk on the subject of "Electroplating" by Mr. C. B. Wilson. Attendance 37.

Rutgers College.—February 15, 1922. Subject: "Electric Propulsion of Ships." Speaker: Mr. W. E. Thau, of the Westinghouse Electric & Manufacturing Company. Attendance 50.

February 20, 1922. The General Electric Company film entitled "Queen of the Waves" was shown. Attendance 15.

A. & M. College of Texas.—February 14, 1922. Subjects: "The Use of Cork-Board for Insulation" by Mr. A. E. Hunt; "Power Plant Efficiency" by Mr. W. W. Lynch. Attendance 39.

Virginia Military Institute.—February 27, 1922. Subject: "Wireless Telegraphy." Speaker: Mr. James Girand. Attendance 67.

March 3, 1922. Combined meeting of all engineering societies. Subject: "Clay Pipes" (illustrated). Speaker: Mr. Hubbard, of the Eastern Clay Products Co. Attendance 200.

Virginia Polytechnic Institute.—February 15, 1922. A description of the Student Engineer's Work at the General Electric Company's plant was given by Mr. A. W. Fairer, Associate Professor of V. P. I. Attendance 19.

University of Virginia.—February 28, 1922. The following General Electric films were shown: "Revelations by X-Ray," "Conquest of the Forest," "A Woolen Yarn," "Our Daily Bread," "Beyond the Microscope." Attendance 63.

State College of Washington.—January 25, 1922. Election of officers as follows: Chairman, Ernest Johnson; Vice-Chairman, Julian O. Swanson; Treasurer, Harold Vance; Secretary, Oscar J. Ball; Reporter, J. Dunkin. Attendance 11.

February 24, 1922. Subject: "Electric Propulsion of Ships." Speaker: Mr. Kratzer '22. Attendance 41.

University of Washington.—March 7, 1922. Motion pictures of the Caribou Hydroelectric Development in California were shown and explained by Mr. W. D. Shannon, former resident engineer of the project. Attendance 180.

West Virginia University.—February 27, 1922. Subjects: "World Communication" by H. Chandler; "Lightning Arresters" by R. D. Brown; "Floodlighting of San Francisco Exposition" by C. M. Hill; "Problems of Motor Transport" by H. C. Daniells. Attendance 23.

March 6, 1922. Subjects: "Life of George Westinghouse" by John Cook; "Electro-Deposition of Tin and Chromium" by W. D. Stump; "Cold Light" by L. D. Tabler; "Electrical Conductivity of the Human Body" by J. L. Hark; "Power

Supply Problem in U. S." by C. R. Lowe; "Battery Charging by Fixed Resistor Method" by C. Snyder; "Electrification of Chilean State Railway" by L. Porter. Attendance 26.

University of Wisconsin.—February 23, 1922. Discussion of the electrical show to be staged April 20-21-22, 1922. Refreshments were served. Attendance 42.

Addresses Wanted

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Eugene A. Baerer, Box 253, Kenvil, N. J.
2.—Waldo C. Cole, 410 Mills Bldg., El Paso, Texas.
3.—O. A. Darnell, 409 East 5th Street, Los Angeles, Calif.
4.—E. W. Erikson, 214 University Club Bldg., St. Louis, Mo.
5.—Victor R. Fisher, U. S. Submarine Base, Coco Solo, Canal Zone.
6.—Walter Scott, 424 Rockingham Street, Toledo, Ohio.
7.—R. W. Seem, 633 West 74th Street, Los Angeles, Calif.
8.—J. Herbert Shanhan, 527 Morris Ave., Elizabeth, N. J.
9.—F. W. Smith, 500 Todd Street, Wilkinsburg, Pa.
10.—Louis H. Wessels, 105 Union Street, Jersey City, N. J.

Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL **should be addressed to EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.,** *the employment clearing house of the Societies constituting the Federated American Engineering Societies, and* **not** *to the A. I. E. E.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case **and forwarded to EMPLOYMENT SERVICE, as above.**

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

Information regarding the notices published is on file in the offices of the member societies of the Federated American Engineering Societies.

OPPORTUNITIES

GRADUATES OF SCHOOL OF ELECTRICAL ENGINEERING of recognized standing, with one or two years practical experience, who can qualify as salesmen. Location, Indianapolis. V-378.

EXECUTIVE SALESMAN. Man to assume marketing problems of a growing middle western concern manufacturing a commodity nationally used in large quantities by makers of motors, transformers, coils, etc. We sell through manufacturer's agents in developed territories. Other areas must be developed to attract agents. All this calls for a fielding sales manager as he will work single handed until his own results justify adding salesmen. We are looking for a proved success but will consider high pressure salesman. accustomed to this class of trade and who is coming fast. In either case appointee must control enough business to make him a success from the start. For such man we will make an opportunity. V-380.

INSTRUCTOR in Electrical Engineering. Start March 1st, if possible. First contract terminating September 1, 1922, possibility of continuing appointment. Send photograph and detailed experience in first communication. Location, Pa. V-396.

UNIVERSITY GRADUATE. Between ages of 25-32. Experienced in design of water power structures. Member of one of the honorary fraternities preferred. Location, New York State. V-421.

DESIGNER. Competent designing engineer experienced in design and development of light automatic machines. Must be capable of carrying design from the experimental model stage to completion of a finished reliable machine ready to be put into production on a practical economical basis. V-426.

LARGE MANUFACTURER OF MAGNET CONTROLLERS has opening for engineer who is familiar with design and application of a-c. and d-c. magnet controllers. Position requires man who has had considerable experience in this line of work and who is capable of taking charge of the development of a line of contractors and controllers for special application. Liberal salary. Location, New York City. V-444.

ELECTRICAL ENGINEERS (2), to assist in operating small electric light power plant, make repairs (minor) include distribution system. Practical experience more important than technical education. Permanent position to right man. Location, West Indies. Application by letter. V-458.

SALES ENGINEER to sell in New York. Complete line of electric motor-driven vertical and horizontal centrifugal pumps. Vacuum heating and condensation pumps. Must have electrical and centrifugal pump experience. One acquainted with plumbing and heating trade and architects of New York preferred. Excellent proposition for capable man. In answering give full details regarding experience, education and age. Application by letter. V-461.

GRADUATE ELECTRICAL ENGINEER for preparation of maps showing electrical transmission lines. By letter only. Location, Pittsburgh, Pa. V-463.

STATISTICIAN between 30-40 years of age with central station and rate engineering experience. Application by letter stating age, education and experience in detail. Location, New York. V-479.

PERSONNEL AND EDUCATIONAL ENGINEER for central station work. Application by letter stating age, education and experience. Location, New York City. V-480.

ARMATURE WINDER for prominent work. Salary for good man is dependent on experience and capability. Interview in person. Location New York City. V-482.

SALES ENGINEER for electro-medical apparatus. Electrical engineering graduate. Application in person. Drawing account and commission. Location, New York City. V-492.

DESIGNERS of electrical switching apparatus oil circuit breakers, carbon circuit breakers and outdoor switching devices. Graduate of good technical school preferred. Application by letter stating age, experience and salary expected. Location, Pittsburgh, Pa. V-514.

SHOP SUPERINTENDENT 35 years of age. Familiar with all phases of machine shop work, small tools and instruments and wireless experience desirable. Application by letter. Location, New York City. V-518.

MECHANICAL ENGINEERING GRADUATE, 1920-21. Man interested in general heat transfer apparatus, water heaters, steam, gas, etc. Personality and ability to handle thermo-dynamics more essential than experience. By letter only. Salary commensurate with ability. Location, New York City. V-519.

ENGINEER age about 21 years. Knowledge of electricity to sell electric specialties in New England. Application in person. Small salary and commission. Headquarters, New York City. V-520.

ENGINEER with electrical experience in factories to estimate work and close contracts on wire and motor work. Work means canvassing for new work as well as estimating. Salary about $20. a week and commission. Location, Brooklyn, N. Y. V-521.

DESIGNER preferably technically trained with several years in power station and substation and preferably high-voltage transmission layout work. "We specify a designer, having in mind that we could use this type of man as a

checker also." No salary stated. Application by letter. Location, New York State. V-522.

ENGINEER who understands shop practise thoroughly and certainly the use of abrasive material in the shop such as emery, carborundum, etc. Must also have the ability to write in simple and convincing manner so that ordinary mechanic can understand. Concern manufactures an abrasive compound which is made of a fast cutting, evenly graded abrasive, mixed with a patented grease binder, which has unusual quality that it will not break down under friction or melt, except in most extreme temperature. Have built up business of many millions of cans a year, throughout the world, and material goes into almost every line of mechanical industry. Within the last year have produced several educational bulletins treating of use of material in different industries, and these bulletins have been so successful that we have finally decided to establish a department and produce carefully prepared bulletins covering as many fields as possible. Application by letter. Location, Norwalk, Conn. V-531.

FACTORY MANAGER experienced in the manufacture of telephone or wireless apparatus. Must have this experience. Location, Mid-West. Application by letter. Salary not stated. V-539.

ELECTRICAL ENGINEER experienced in wireless apparatus for sales work. Will work as inside salesman on salary and commission. Application by letter. Location, New York City. V-542.

INSTRUCTOR to teach mechanics in southern institution for the year 1922-23. Some successful experience in handling men would be more acceptable, but recent graduate with good record would be considered. Application by letter. Location, Fla. V-544.

YOUNG CIVIL OR ELECTRICAL ENGINEER who has had some experience in maintenance of city street railway tracks and overhead lines. Position would require residence in Mid-West. Will have supervision over maintenance of 59 miles of both open and paved track together with overhead lines used in connection therewith. On account of size of property salary which could be paid at start would be nominal one, but owing to affiliations of company opportunity for transfer to other departments is very good, and ultimate position which could be held by such a man would rest entirely with himself. Application by letter stating age, education and experience. Location, Ohio. V-545.

ERECTING ELECTRICAL INSPECTOR to handle work on the Pacific Coast. Will be located either in Seattle or San Francisco. Must be located in this vicinity. Application by letter. Salary not stated. V-548.

ENGINEER with extensive design experience on fittings for overhead catenary line construction and transmission lines. In replying, state age, experience and salary expected. Location, Pittsburgh, Pa. V-557.

ELECTRICAL ENGINEER recent graduate to join organization as salesman. Duties would be to call upon mills of New England selling chemical goods and supplies for electroplating and polishing. Must be well grounded in electrical engineering and must be familiar with and be able to sell apparatus used in electro-plating, and must also be able to give advice on subject of electroplating. Application by letter. Salary not stated. Location, Waterbury, Conn. V-567.

INSTRUCTOR, electrical engineering degree, to teach freshman technical physics; some work in precise electrical measurements and a-c. course for mechanical engineers. Prerequisites, teaching and practical experience, personality and character. Begin September. Salary not stated. Location, East. V-608.

MEN AVAILABLE

YOUNG ELECTRICAL ENGINEER—age 24, single, 15 months G. E. test, 13 months synchronous machinery design, 4 months power system appraisal work. Desires connection that will help to fit him to become a consulting engineer or business executive. Primary consideration is a chance to prove worthiness rather than first salary. E-3242.

ENGINEER—Chemical and Electrical, with 15 years broad experience in development work in chemical and related industries. Is best fitted to carry out work on the improvement of quality of product and on the solution of difficult problems of operation and process control. Experience in pulverizing, mixing, crystallization, fractional distillation industrial furnaces and other special lines. E-3243.

ELECTRICAL ENGINEER—technical education, Assoc. A. I. E. E., age 25, married. Two years experience in engineering department of company manufacturing Quartz Mercury Vapor Lamps for therapeutic use. Familiar with ultraviolet ray apparatus used in water sterilization. Available May 1st. E-3244.

ENGINEER with 10 years experience, 6 of which were with large central station distribution department. Two in electrical construction dept. of steel company, and past two on the road as erection engineer for concern manufacturing turbo alternators. Desires position in distribution department. Age 29. Salary $3000. Any location in U. S. A. E-3245.

GRADUATE MECHANICAL ENGINEER—steel plant and factory experience. Teaching university mechanical laboratory and graduate student. Aeroplane supervision and purchasing for aero-engine factory. Broad experience along engineering inspection. Considerable construction and erection work. Production engineer, State of Pennsylvania during War and later at an armor plant. Investigations, appraisals and cost accountant work. E-3246.

ASSISTANT SUPERINTENDENT OR DISTRIBUTION ENGINEER, or both, of medium size or small central station system. Technical education and several years experience in nearly all departments of light and power business, including special training in distribution engineering. Age 31. Now employed in similar capacity with property of 6000 customers. E-3247.

ELECTRICAL ENGINEER—Technical education, Assoc. A. I. E. E. Former Engineering Officer U. S. Navy. Wide experience with manufacture, installation and maintenance of d-c. equipment and storage batteries. Also experience with automotive electrical work, railway car lighting, and factory maintenance with a-c. Equipment. Age 33. Married. Located in Kansas. E-3248.

YOUNG ENGINEER—age 30, American citizen, single, five years experience after graduation from American University. Educated in Germany. Knows country and language thoroughly. Associate A. I. E. E. Wish to go to Germany for American company as technical correspondent, representative or investigator. Best of references. E-3249.

ENGINEER—EXECUTIVE—Mem. A. I. E. E. Experienced in Oriental and European practise, having broad American experience in responsible charge of central station and industrial developments, invites correspondence. Has good record as organizer and director of both business and technical departments. Now completing foreign investigation. Available early summer. Correspondence immediate. E-3250.

ELECTRICAL ENGINEER—technical graduate; Assoc. A. I. E. E. Age 28. Six years experience in testing laboratory, radio, chief engineer of marine installation and maintenance; remote control, machine tool application, estimating and construction work. Desires permanent position with well established company, planning, estimating and following up progress of jobs. Location preferred Newark or New York City; available one month. E-3251.

ELECTRICAL ENGINEER—with 18 years experience in design, construction and maintenance of electrical equipment in industrial plants, desires permanent position, engineering concern. E-3252.

ELECTRICAL ENGINEER—Technical graduate. Six years experience power-plant, substation and transmission line construction and layout. General Electric Co. Test. Available on short notice. E-3253.

YOUNG ELECTRICAL ENGINEER—University of Minnesota 1921 desires position as assistant to executive with electric utility or consulting engineer. Six years experience in small utility construction, operation and management. Observing, energetic and dependable. Available on short notice. Location, Middle West preferred. E-3254.

GRADUATE ELECTRICAL ENGINEER—age 24, single, available on short notice. One year of testing experience with the General Electric Co. Well acquainted with electrical apparatus of all kinds. Would prefer outdoor work as construction or sales, but will consider any position where there is a chance to work in with the concern. E-3255.

GRADUATE ELECTRICAL ENGINEER—Experience with Public Service Commission, New York State; also teaching experience in electrical engineering, theory and practise. Desires change for broader field of activity; initiative and perseverance; age 25; married; present salary $2000; available on reasonable notice. E-3256.

EXPORT ENGINEER—Graduate electrical and mechanical engineer, at present in charge of electrical department, with large contracting and designing engineering company, desires connection with firm needing a man thoroughly acquainted with the electrical industries of this country, through 12 years experience and also familiar with languages and social conditions in the Scandinavian countries. E-3257.

CONSTRUCTION ENGINEER WANTS INTERVIEW with any concern needing a man of the following qualifications: E. E. and B. E. degrees, married; age 31; ten years experience in the installation of over 300,000 horse power in electrical and hydroelectric equipment. Experience embraces cofferdam work, concrete dam construction, general reinforced concrete, structural steel, and all apparatus from water-wheel to consumer. Minimum salary $3600. E-3258.

MECHANICAL AND POWER ENGINEER, technical graduate, B. S. and M. E., eight years experience, machine shop, metallurgy, sugar engineering, industrial and power plant practise, operation, design, layout, calculations, heat-balance, utilization and distribution of steam, water, coal, power, etc., investigation, research, reports. Executive and business ability. E-3259.

YOUNG UNDERGRADUATE—Assoc. A. I. E. E. Two years experience on mechanical production work and five years extensive theoretical and practical experience in electrical laboratories of large light and power company, desires position which he can occupy during long summer vacations with the idea of fitting himself for greater responsibilities on graduating. Can supply excellent references. E-3260.

YOUNG MAN—24, recent technical graduate with electrical engineering degree is willing to start at the bottom in any work related to engineering. Has business ability. Manufacturing or testing desired. E-3261.

TECHNICAL GRADUATE OF ELECTRICAL ENGINEERING COURSE—age 23, desires

a position with an opportunity for advancement. Has four years of good practical experience in shop work, electrical testing, and drafting in both manufacturing and public utility concerns. E-3262.

TECHNICAL STUDENT, age 25, single, graduate civil engineer University of Caracas, Venezuela. Completed electrical engineering evening course at Columbia University, New York City. Seven years experience in electrical testing and hydroelectric work with prominent companies both in this country and in Venezuela. Desires permanent position in Cuba with electrical concern. E-3263.

ELECTRICAL ENGINEER—British. Assocs A. I. E. E. Technical graduate. City-Guild' Inst. (London). Four years general electrical engineering, 6 years, generation and transmission of power and electric lighting schemes, a-c. and d-c. Two years central station executive in technical capacity. Desires position, foreign service preferred or Western States. Moderate salary, single, age 28. E-3264.

SPECIALIST ON ELECTRIC METERS. Married, age 27; twelve years experience in all branches of meter work. Trained by large company. Started at bottom and have since successfully organized and systematized meter departments for several companies. Hard work my specialty. Permanent position desired, anywhere. Employed at present but available on short notice. Good References. Minimum salary $2400. E-3265.

ENGINEER—University man. Associate A. I. E. E. Executive. Thoroughly experienced in the design of electric resistors, transformers, universal motors, thermostats. $3600. E-3266.

YOUNG ELECTRICAL ENGINEER, technical education, student A. I. E. E. Desires position in electrical engineering; design or construction work; or general plant engineering. Location immaterial. Reasonable offer considered, according to responsibility. Available about June 15. E-3267.

GRADUATE ELECTRICAL ENGINEER—age thirty, Assoc. A. I. E. E., five years experience in design and estimating of power plants, substations, distribution and transmission systems with two large power companies. Desires responsible position with power company or industrial concern. Available on short notice. Excellent references. E-3268.

ELECTRICAL ENGINEER—graduate of 1917, desires work in field of radio, telephone, or electrical engineering. Has had approximately one year's experience in each. Completing second year of college teaching. Available late in June. Prefer middle west. Single. E-3269.

GRADUATE ELECTRICAL ENGINEER—G. E. test, age 33, married. Has been chief safety engineer in workmen's compensation field; excellent experience in safety code work. Now doing technical and publicity work in general insurance; present salary $4500. Would accept responsibility for safety, insurance or analytical work in industrial plant or utility. E-3270.

ELECTRICAL ENGINEER, technical graduate, age 33. Ten years with large electrical manufacturing company as engineer in charge of design, estimating, and consulting; two years design and construction of power houses and substations for mining company. Desires position where experience can be capitalized. Available June 1. E-3271.

YOUNG MAN—Age 23, single, will receive B. S. degree in electrical engineering next June. Enrolled student, A. I. E. E. Commercial course, speaks and writes Bohemian, studied Spanish. Location immaterial, foreign service considered. Not afraid of work. E-3272.

ELECTRICAL ENGINEER with fourteen years experience in design of electric stations and distribution systems and engineering problems of public utility properties with large engineering and group operating organization, investigations, reports, appraisals and supervision of construction. Two years experience as plant engineer for large industrial company. Married. Age thirty-eight. E-3273.

ELECTRICAL ENGINEER—Age 24, single, Associate A. I. E. E., graduating from a recognized University in May. Has had about five years experience with large hydroelectric system in construction, maintenance and draughting. Desires position immediately on graduating, and will go anywhere, but preferably South America. Good references provided if required. E-3274.

GRADUATE ELECTRICAL ENGINEER—M. I. T. (S. B. and S. M.), age 25, with 2 years technical teaching and 2 years management engineering experience desires a further connection in production or sales engineering. Employed at present. Location, Eastern Coast. E-3275.

ELECTRICAL ENGINEER AND TEACHER, broadly educated, adaptable, agreeable personality, successful administrator, accustomed to new undertakings and responsibilities, seventeen years' diversified experience including non-electrical branches, nine as head of university department, desires change for larger constructive activity, commercial, technical, or educational. E-3276.

GENERAL MANAGER—Over twenty years experience in construction, operation, management, public utilities. General manager large railway gas and power company prior to the war. Knows the business from the coal pile to the public. Successful executive, energetic and tactful, age 47, married, American, several years experience abroad. Speak Spanish. Available now. E-3277.

ELECTRICAL ENGINEER AND COST ACCOUNTANT—age 32. Ten years' experience in the theory, design, manufacture and accounting of the insulated wire and cable industry. Demonstrated and proved executive ability. Desirous of connecting with a firm where my knowledge will prove beneficial, or am willing to enter in any other field as an engineering accountant. Locality in or about New York City. Available within two week's notice. E-3278.

ELECTRICAL ENGINEER, age 24, single. Technical education. Eight years practical experience in manufacture, test, and maintenance of electrical machinery and equipment. Nineteen months with General Electric Co. on engineering service, desires position as chief electrician or research engineer. Would also consider position on engineering service work. E-3279.

SUPERINTENDENT OF CONSTRUCTION AND DISTRIBUTION—Sixteen years with light and power companies. Fourteen years with present company. Have designed, constructed and operated substations, distribution and transmission lines in the Niagara Falls district including suburban and rural road lighting. Age 36. Married. Associate A. I. E. E. Available May 1st. E-3280.

CHIEF ELECTRICIAN—Assoc. A. I. E. E. Age 38, married. Three years technical education and 20 years practical experience laying out, installation and maintenance of lighting, switchboards, generators, motors, etc., in industrial plants. Minimum salary $2400. Central States preferred. E-3281.

ENGINEER with broad engineering, executive and business training, age 43, graduate E. E. Industrial engineering and development. Engineering and development. Engineering and financial reports. Studies of processes, organization, costs and improvements. Plant layouts. Power and lighting. Public utility valuations. Transmission line and electric railway, design, construction and maintenance; power stations, distribution, cars. E-3282.

GRADUATE ELECTRICAL APPRENTICE OF GENERAL ELECTRIC COMPANY, age 23, single, desires position with growing electrical manufacturing concern in Central States offering opportunity for advancement. Two years electrical drafting experience, one year testing fractional horse power motors. Familiar with electrical apparatus in general; salary secondary factor. Available on reasonable notice. E-3283.

RESEARCH ENGINEER—First-class education in electrical engineering and physics; several years experience on various engineering problems involving design of instruments, study of materials and rotating machinery. Would consider a suitable position anywhere if prospects are good. Details and references will be furnished upon request. E-3284.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MARCH 17, 1922

ALLAN ARTHUR, Substation Foreman, Braden Copper Company, Rancagua, Sewell, Chile, S. A.

*ALLANSON, HENRY E., Partner, Automotive Electrical Specialists, 557 A Yonge St.; res., 217 Humberside Ave., Toronto, Ont.

ALLEN, CHARLES HENRY, Inspector, Toronto Hydro-Electric System, 226 Yonge St., Toronto, Ont.

ANDERSON, J. E., Manager, Maquoketa & De Witt Division, Iowa Electric Company, Maquoketa, Iowa.

BAILEY, CECIL, Power Plant Operating Engineer, Radio Corporation of America, 923 Fort St., Honolulu, T. H.

BARKSDALE, JOHN POWELL, Electrical Engineer, J. C. Sullivan Coal Interests, Tralee; res., 319 Summers St., Charleston, W. Va.

BARTHE, CYRIL STUART, Manager, Toronto District Supply Sales, Canadian General Electric Co., Ltd., Toronto, Ont.

*BARTLETT, CARROLL ARCHER, Telephone Engineer, American Tel. & Tel. Co.; res., 801 E. 157th St., Cleveland, Ohio.

BAUER, C. MAMERDO, Assistant Electrical Foreman, Mine, Braden Copper Company, Rancagua, Sewell, Chile, S. A.

*BEUTTER, ERWIN G., Operating Dept., The Electric Storage Battery Company, 101 West End Ave., New York, N. Y.

BIGELOW, HORACE HOLLY, Electrical Inspector, City of Worcester, 11 City Hall, Worcester, Mass.

*BISH, HOWARD P., Marine Engineer, General Electric Company; res., 107½ Furman St., Schenectady, N. Y.

BLAKESBOROUGH, HAROLD ABBOTT, Superintendent of Public Utilities, City of Kelowna, Kelowna, B. C.

BLOOMFIELD, JAMES MUNRO, Electrical Engineer, General Engineers, Ltd.; Suite 4, Mount Royal Apts., 7th St. West, Calgary, Alta., Canada.

BORGGRAFE, EDWARD W., Electrical Engineer, Electric Specialty Company, 211 South St., Stamford, Conn.

BORGHARD, A. W., Electrical Salesman, Ward Leonard Electric Company, Mt. Vernon, N. Y.

*BOYER, GARTH CLIFFORD, Assistant Engineer, State Corporation Commission of Virginia, Richmond, Va.

BRIEGER, LAWRENCE, New York Edison Company, 327 Rider Ave.; res., 206 W. 148th St., New York, N. Y.

BROWNLEY, EDWARD, Assistant Superintendent of Operation, New York & Queens Electric Light & Power Company, Long Island City; res., 123 Jamaica Ave., Astoria, L. I., N. Y.

BUCHANAN, HAROLD FRANK, Commerical Engineer, International General Electric Company, Schenectady, N. Y.

BUCHANAN, JAMES RAMSEY, Chief Engineer, Sylva Tanning Company, Sylva, N. C.

BUNSTER, FERDINAND HECTOR, Switchboard Operator, Braden Copper Company, Rancagua, Sewell, Chile, S. A.

BUTTERWORTH, ALFRED, Electrical Engineer, Cawnpore Woolen mills, Cawnpore, India.

CARGILL, CHARLES GILMORE, Representative, H. Alexander, Inc., 25 West 33rd St., New York, N. Y.

CARR, JAMES MILLS, Division Electrical Foreman, Braden Copper Company, Rancagua, Chile, S. A.

CARROLL, JERRY, Secretary & Manager, Mauston Electric Service Company, Mauston, Wis.

CAWLEY, WILLIAM H., Assistant to Supervisor of Transmission Maintenance, Mountain States Tel. & Tel. Company, 412 Wyoming Bldg., Denver, Colo.

CHACON, ERNESTO, Electrical Foreman, Mine Division, Braden Copper Company, Rancagua, Chile, S. A.

CURLEE, LOUIS C., Construction Superintendent, Mill & Mine Engineers, Inc., 1101 American Trust Bldg., Birmingham, Ala.

DAMOISEAU, EDWARD W., Electrician with E. C. Louis, Federal St.; res., 272 Shawmut Ave., Boston, Mass.

DANIELL, ALLIE GREENBERRY, Load Dispatcher, Georgia Railway & Power Company, 24 E. Alabama St., Atlanta, Ga.

DANNATT, SAMUEL HAMILTON, New York Manager, Electric Service Supplies Company, 50 Church St., New York, N. Y.

DAVIS, GEORGE ELTON, Instructor, Technical Training Dept., Western Electric Company, 463 West Street, New York, N. Y.

*DEAL, HARMAN B., Assistant to General Manager, Missouri Public Utilities Co.; Cape Girardeau-Jackson Interurban Railway Co.; College Hill, Cape Girardeau, Mo.

De CAMP, HERBERT C., Assistant General Manager, City Railway Company, Dayton, Ohio

*DE TARNAVA, CONSTANTINO, JR., Monterrey, Mexico.

EAGIN, JOHN JOSEPH, Assistant Electrical Engineer, Transit Commission, 49 Lafayette St., New York, N. Y.

EMMONS, NORMAN EUDELL, Electrical Foreman, Stone & Webster; 68 Imlay St., Hartford, Conn.,

ETCHES, GERALD DENIS, Engineer, Marconi Wireless Telephone Company of Canada, Ltd., Marconi Towers, Glace Bay, N. S., Canada.

EXCELL, STEPHEN HENRY, City Engineer, City Hall, Vernon, B. C.

FLEISHMANN, EDWIN, Student, Harvard Engineering School, 39 Weld Hall, Cambridge, 38, Mass.

FOSMIRE, HOWARD LESLIE, Student Engineer, General Electric Company; res., 20 Bedford Road, Schenectady, N. Y.

FREYER, ARTHUR L., Chief Inspector, Northern Indiana Gas & Electric Company; res., 229 Detroit St., Hammond, Ind.

GAARDEN, OSCAR, Sales Engineer, Northern States Power Company, 15 S. 5th St., Minneapolis, Minn.

GEORGE, BERTRAND L., Foreman of Electrical Construction, Shawsheen Mills, Andover, Mass.

GRANZOW, HERMAN F., Electrician, Braden Copper Company, Rancagua, Chile, S. A.

GREIG, JOHN WHITTIER, Transmission Dept., Pacific Tel. & Tel. Company, 3306 11th Ave. West, Seattle, Wash.

GRISWOLD, PHELPS E., District Inspector, American Tel. & Tel. Company, 318 Telephone Bldg., Omaha, Neb.

HADLEY, HOMER L., Electrical Engineer & Estimator, Allis-Chalmers Mfg. Company, West Allis, Wis.

HAMBLETON, JOSEPH THOMAS, President & General Manager, Slate Belt Transit Company; res., 440 Penna. Ave., Pen Argyl, Pa.

HARRELL, WILLIAM F., Draftsman, Skagit River Power Development, 110 Cherry St., Seattle, Wash.

HARRINGTON, GEORGE RAYMOND, Electrical Dept., H. C. Frick Coke Company; res., 522 Walnut Ave., Scottdale, Pa.

*HARTMAN, WALTER K., Sales Engineer, Century Electric Company, 4130 McPherson Ave., St. Louis, Mo.

HAUCK, LOUIS W., Electrician, Union Electric Light & Power Company; res., 3735a Louisiana Ave., St. Louis, Mo.

*HAUER, THEODORE M., Assistant Engineer, Day & Zimmermann, Inc., 611 Chestnut St.; res., 1932 S. Salford St., Philadelphia Pa.

HEGER, FRANCIS E., Assistant Engineer, Interborough Rapid Transit Co., 165 Broadway, New York, N. Y.

HELLER, WILLIAM HENRY, Electrical Inspector, Board of Fire Underwriters, 316 Walnut St., Philadelphia, Pa.; res., South Main St., Pleasantville, N. J.

HELVIE, ROSCOE SHIVELY, Assistant Electrical Engineer, Havana Central Railroad Company, Havana, Cuba.

HENDRICKSON, LEO WALTMAN, Electrical Foreman, Braden Copper Company, Rancagua, Chile, S. A.

*HOAG, PAUL WILLIAM, Electrical Tester, General Electric Company; res., 909 Weschler Ave., Erie, Pa.

HOAGLAND, LYMAN EDWARD, Sales Engineer, Century Electric Company, 1827 Pine St., St. Louis, Mo.

HOELLE, MARTIN R., Electrical Supervisor, Western Maryland Railway Company, Hagerstown, Md.

HOFFECKER, FRANK SHAWN, Power House Switchboard Operator, Bethlehem Steel Company, Sparrows Point; res., 4 Eastship Road, Dundalk, Md.

*HOUNSELL, E. VICTOR, Field Man, Southern California Telephone Co., Los Angeles; res., 604 S. Glendale Ave., Glendale, Calif.

HOWARD, LAWRENCE FAY, Engineering New Stations, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.; res., 130 Bergen Ave., Ridgefield Park, N. J.

HUBBELL, HAROLD FARNSWORTH, 1st Lieut., Signal Corps., U. S. A., 3rd Signal Co., Camp Lewis, Wash.

*HUNT, OZRO HAROLD, Testing Dept., General Elec. Company; res., 24 Eagle St., Schenectady, N. Y.

*ISAAC, ROSA D., Draftswoman, The Pacific Tel. & Tel. Company; res., 2455 Vallejo St., San Francisco, Cal.

JENSEN, AAGE WILLIAM OTTO, Draftsman, Western Electric Company, 4412 W. Madison St., Chicago, Ill.

JOHNSON, OSCAR, Motor Inspector, Acme Service Corp., 246 Canal St.; res., 159 E. 109th St., New York, N. Y.

JORGENSEN, JESSE JEAN, Superintendent, Colon Telephone Company, Cristobal, C. Z.

JUDKINS, ERNEST LAROY, Power & Mining Engineering Dept., General Electric Company; res., 1315 Albany St., Schenectady, N. Y.

KEATING, LEONARD MATHEW, Commercial Engineer, The Ohio Brass Company, Mansfield, Ohio.

*KEIFFER, LAWRENCE R., Electrical Engineer, National Lamp Works, Nela Park, Cleveland, Ohio.

*KELLER, ARTHUR CHARLES, Engineering Dept., Western Electric Company, 463 West St.; res., 1744 Garfield St., Van Nest, New York, N. Y.

KELLEY, ARTHUR MILTON, Testman, Plant Dept., New England Tel.& Tel. Company; res., 390 Maxfield St., New Bedford, Mass.

*KERR, EDWIN M., Instructor, Manual Arts and Mechanical Drawing, Tonopah Public Schools, Tonopah, Nevada.

KING, KARL T., Student Telephone Engineer, American Tel. & Tel. Company, 1422 Hurt Bldg., Atlanta, Ga.

KINGSTONE, GEORGE ALEXANDER, Manager, Dominion Carbon Brush Company, 38 Duke St., Toronto, Ont., Canada.

LAND, EDMUND, Telephone Engineer, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

*La ROSA, LEONARD, Manager, Star Electric Company, 334 5th St.; 226 Canal St., New York, N. Y.

LEIBING, SIDNEY C., Power & Mining Engineering Department, General Electric Company, Schenectady, N. Y.

LeMASTER, WILLIAM A., Salesman, Hoover Suction Sweeper Company; res., 1802 Victor St., St. Louis, Mo.

LERCH, CHARLES WARREN, Engineer, Motor Engineering Dept., Westinghouse Elec. & Mfg. Company, E. Pittsburgh, Pa.

LINDNER, HERBERT G., Facilities Engineer, Wisconsin Telephone Company; res., 1118 Hayes Ave., Milwaukee, Wis.

LLOYD, LEONARD R., No. 4 North St., Napier, New Zealand.

LYNAM, JOSEPH P., Assistant Substation Operator, United Electric Light & Power Company, 130 E. 15th St., New York; 63 S. Oxford St., Brooklyn, N. Y.

MAGUIRE, FRANCIS A., Engineering Dept., Wisconsin Telephone Company; res., 232 18th St., Milwaukee, Wis.

*MANDERFELD, EMANUEL C., Electric Dept., University of Minnesota; res., 1827 4th St., South East, Minneapolis, Minn.

McALLISTER, ARCHIBALD, Division Leader, New York Edison Company, 170th St. & Inwood Ave., New York, N. Y.

McCRACKEN, GLENN WORTH, Engineer, Compania Electrica de Alumbrado y Traccion, Apartado 110, Santiago, Cuba.

McDONALD, HUGH DUDLEY, Station Foreman, Braden Copper Company, Rancagua, Chile, S. A.

McKEEVER, FREDERICK LEONARD, Municipal Electrical Engineer, Penticton, B. C., Canada.

MEIER, ROBERT AUGUST, Check Inspector Central Offices, Western Electric Co., Inc., 104 Broad St., New York: res., Lynbrook, N. Y.

MEYER, EDWARD GEORGE, Electrical Engineer, The Industrial Manufacturing Co., 512 Indiana Pythian Bldg., Indianapolis, Ind.

MILLER, BENJAMIN L., Equipment Engineer, Wisconsin Telephone Company; res., 543 69th Ave., Milwaukee, Wis.

MOLTEDO, LOUIS P., Gilchrist Company, 495 Washington St.; res., 25 Breed St., Orient Heights, Boston, Mass.

MONNICH, MAURICE JOHN, Foreman, Electrical Branch, Martz Construction Company, Seward, Nebr.

MOODY, DWIGHT LYMAN, Telephone Engineer, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

MORRY, HISAGORO, Electrical Engineer, Nippon Electric Power Company, Osaka, Japan.

NAKANO, KWANJI, Electrical Engineer, Kawasaki Zosensho, Kobe, Japan.

*NECKERMAN, WILLIAM GEORGE, Telephone Maintenance, New York Telephone Company, New York, N. Y.; res., 408 13th St., West New York, N. J.

NORONHA, EDGAR FELNER, Maintenance Inspector, Elec. Mill Equipments, Tata Hydro Electric Power Supply Co., Ltd., Fergusson Road, Bombay, India.

O'HALLORAN, JAMES, Master Mechanic, Swift Canadian Company, Toronto, Ont., Canada.

OTTO, EDMUND GERHARD, Electrical Engineer, The E. G. Otto Electric Company, Inc., 440 Central St., Franklin; res., Hill, N. H.

PAGE, DONALD WILLIAM, Foreign Manager, Aluminum Company of S. America, Apartado 900, Madrid, Spain.

PAGE, HARRY S., Designing Engineer, D. C. Engineering Dept., General Electric Company, Schenectady, N. Y.

PAINTON, PERCY RALPH, Superintendent of Maintenance, Rio de Janeiro & Sao Paulo Telephone Co.; Caixa do Correio 571, Rio de Janeiro, Brazil, S. A.

PHILLIPS, JAMES EDGAR, Load Dispatcher, Georgia Railway & Power Company; res., 101 Cascade Ave., Atlanta, Ga.

PIGOTT, JOHN ARDSLEY, Electrical Engineer, Waitara Borough Council, Power Station, Queen Str., Waitara, N. Z.

PIPES, PLINY PLEUTARCH, Engineer, Welding Dept., Lincoln Electric Company, 105 W. 40th St., New York, N. Y.

PIROTH, CHARLES JACOB, Service Inspector, Duquesne Light Company; res., 1708 W. Liberty Ave., Pittsburgh, Pa.

POOLE, HERBERT HERSEY, Chief Electrician, Atlantic Dyestuff Company, Portsmouth, N. H.

*PRIEST, CONAN ALTHADO, Student, University of Maine, Orono; res., 8 Pleasant St., Ellsworth, Maine.

PUTNAM, JOHN PICKERING, Draughtsman, Narragansett Electric Lighting Company; res., 22 George St., Providence, R. I.

RAY, BANKIN CHANDRA, Electrical Engineer of Maharajadhiraj of Darbhanya, Raynagar, Darbhanya, India.

RAYMOND, HAROLD NEWNHAM, Power Installer, Northern Electric Company, Montreal, P. Q.

READING, WILLIAM RICHARD, Installer, Plant Dept., Western Union Telegraph Company, Denver, Colo.

*REED, OLIVER PUTERBAUGH, Electrical Distribution Dept., Denver Gas & Electric Company, Denver, Colo.

*REID, HENRY JOHN EDWARD, Junior M. E., National Advisory Commission for Aeronautics, Langley Field, Hampton, Va.

REIDENBACH, ALFRED H., Telephone Engineering, New York Telephone Company, 104 Broad St., New York, N. Y.

*REITZ, HAROLD JOHN, Testing Dept., General Electric Company; res., 417 Union St., Schenectady, N. Y.

RILEY, WESTON K., District Engineer, The Del. & Atl. Tel. & Tel. Company, Camden, N. J.; res., 5762 Hunter St., W. Philadelphia, Pa.

RISKO, WILLIAM, Engineering Assistant, Bell Telephone Company of Pennsylvania, Philadelphia; res., 6221 Clearview St., Germantown, Pa.

RITCHIE, ERNEST SAMUEL H., Head Teacher, Electrical Engineering, Drawing & Design, Technical College, Sydney, N. S. W., Australia.

ROBERTS, EVERETT L., Instructor, University of Maine, Orono; res., 34 6th St., Bangor, Me.

ROSS, WILLIAM DONALD, Electrician, Thompson & Castleton, Inc.; res., 6335 40th Ave., S. W., Seattle, Wash.

SCHEU, LESTER W., Meter Engineer, Hickok Electrical Instrument Company; res., 521 E. 109th St., Cleveland, O.

SCHROEDER, GILBERT W., Junior Engineer, The Milwaukee Electric Railway & Light Company; res., 1428 Wright St., Milwaukee, Wis.

SCOTT, LORENZO J., Manager, United Electric Light Company, 73 State St., Springfield, Mass.

SEITANIDES, GEORGE BASIL, Asst. Superintendent, School of Engineering, Robert College, Constantinople, Turkey.

SINGER, LESLIE RUSSELL, Engineer in charge of Iowa, Nebraska United Iron Works, Inc., Kanasas City Mo; 513 United Bank Bldg., Sioux City, Ia.

*SINGLETON, LOUIS WINFIELD, Stone & Webster, Washington, D. C.; res., Elk Ridge, Maryland.

SKOLFIELD, WILLIAM K., Electrical Engineer, Induction Motor Engineering Dept., General Electric Company; res., 230 Union St., Schenectady, N. Y.

SMITH, OLIVER C., Transmission Engineering Dept., The Pacific Tel. & Tel. Company, 601 Telephone Bldg., Seattle, Wash.

SOULE, MARTIN HAYDEN, Superintendent, Intermountain Railway, Light & Power Company, Laramie, Wyoming.

SPAIN, CARL JAMES, Supervisor, Electrolysis & Inductive Interference, Pacific Tel. & Tel. Company; 309 E. 8th St., Los Angeles, Calif.

*STANFIELD, JOHN HANNIBAL, Student Engineer, Chicago Elevated Railroads; res., 1370 E. 54th St., Chicago, Ill.

STEWART, EDWARD N., Laboratory Foreman, Dayton Power & Light Company; res., 2228 Lakeview Ave., Dayton, Ohio.

STOUT, FRED H., Electrical Inspector, Hatfield Electric Company; res., 710 Russell Ave., Indianapolis, Ind.

STREED, S. MARTIN, Electrical Inspector, City of Minneapolis; res., 3228, 10th Ave. South, Minneapolis, Minn.

*SULLIVAN, GEORGE L., Testing Dept., General Electric Company, Schenectady; 115 Sanders Ave., Scotia, N. Y.

SWIFT, GEORGE W., Chief Switchboard Operator, United Electric Light Company: res., 125 Ranney St., Springfield, Mass.

TAKASAKI, HITOSHI, Electrical Engineer, Government-General of Choson; Mitsui & Co., 65 Broadway, New York, N. Y.

*TEAGUE, WILLIAM LEWDY, Instructor in Electrical Engineering, University of Arkansas; res., 314 West Center St., Fayetteville, Ark.

*TRIEM, RALPH HAMILTON, Teacher of Mathematics, Hilo High School, Hilo, Hawaii; La Port City, Iowa.

VAN DER POLL, JAN A., Westinghouse Electric & Mfg. Company, New York; res., 1710 73rd Street, Brooklyn, N. Y.

*VAN HOUTEN, LESLIE PERRINE, Telephone Service Supervisor, American Tel. & Tel. Company; res., 930a Hamilton Ave., St. Louis, Mo.

VAUGHAN ELEAZER ALBERT, Superintendent, Lompoc Light & Power Company; res., 139 N. E. St., Lompoc, Calif.

VAZQUEZ, DANIEL A., JR., Testing Dept., West Penn Power Company, Springdale, Pa.

von NOSTITZ, ERICH, Engineer, Dept of Development & Research, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

WARD, PHILIP H., JR., President, Ward Electric Company, Otis Bldg., Philadelphia, Pa.

WEATHERS, ETHELBERT W., Manager, Weathers Electric Motor Shop, 818 "F" St., San Diego, Calif.

WEAVER, ALBERT, Electrical Engineer, General Electric Company; res., 5 Spruce St., Schenectady, N. Y.

WENTE, LESLIE H., Manager, Wente Electric Company, 223 No. Fourth St., Hamilton, Ohio.

WILLIAMSON, CARL HENRY, Telephone Engineer, St. Louis & San Francisco Railway Company, 306 Frisco Bldg., Springfield, Mo.

WILSON, RICHARD LITTLE, Wire Chief, Braden Copper Company, Rancagua, Sewell, Chile, S. A.

WUICHET, RICHARD P., Assistant Electrical Engineer, Dayton Power & Light Company, 50 S. Jefferson St., Dayton, Ohio.

YOUNG, HAROLD EUGENE, Sales Manager, Northern States Power Company, 15 S. 5th St., Minneapolis, Minn.

Total 159.

*Formerly enrolled students.

ASSOCIATE REELECTED MARCH 17, 1922

SCHABINGER, FREDERICK, System Operator, Interboro Rapid Transit Company, 600 W. 59th St., New York, N. Y.

MEMBERS ELECTED MARCH 17, 1922

BEAR, WILLIAM PETER, Electrical Engineer, Staff-William G. Woolfolk, 1620 Edison Bldg., Chicago, Ill.

BUDLONG, GUY V., Electrical Engineer, American Steel & Wire Company; res., 113 Elm St., Worcester, Mass.

COGHLIN, PETER A., President & Treasurer, Economy Electric Company, 22 Foster St., Worcester, Mass.

FIELD, ERNEST LINWOOD, Electrical Engineer, Stone & Webster, 147 Milk St., Boston, Mass.

GANTT, ROBERT ANDERSON, Chief Engineer, North-Western Bell Telephone Company, Omaha, Nebr.

HAHN, CLIFFORD AYLWARD, Engineer, Stone & Webster, Inc., 147 Milk Street., Boston, Mass.

HILYER, WILLIAM JOHN, Chief Engineer, Egyptian State Telegraphs, Cairo, Egypt.

HULSE, GEORGE EGBERT, Chief Engineer, Safety Car Heating & Lighting Company; res., 129 Whally Ave., New Haven, Conn.

JUDSON, WALTER RAYMOND, District Manager, Allis-Chalmers Mfg. Co., Casilla 2653, Santiago, Chile, S. A.

KOSITZKY, GUSTAV ADOLPH, Chief Engineer, The Ohio Bell Telephone Company, 4300 Euclid Ave., Cleveland, Ohio.

McCARN, GEORGE EASTMAN, Chief Engineer, The Mountain States Tel. & Tel. Company, Denver, Colo.

NICELY, RALPH N., Telegraph Engineer, Long Lines Dept., American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

OSTROM, WELLINGTON ROSS, District Manager, Northern Electric Company, Ltd., 131 Simcoe St., Toronto, Ont.

PURCHAS, ROBERT WHITTLESEY T., Purchasing Agent, Northern States Power Co., 15 So. 5th St., Minneapolis, Minn.

RANGER, RICHARD HOWLAND, Engineer, Radio Corporation of America, 233 Broadway, New York, N. Y.

RATCLIFF, HENRY AUGUSTUS, Superintendent Electrical Engineer, Manchester Corporation Electricity Works, Dickinson St., Manchester, England.

SCHOFIELD, ROBERT HARRY, Director, Ferranti Meter & Transformer Co., Ltd., Hollinwood, Lancashire, England.

TUTHILL, JOHN KLINE, Assistant Professor of Railway Electrical Engineering, University of Illinois, 106 Transportation Bldg., Urbana, Ill.

TRANSFERRED TO GRADE OF MEMBER MARCH 17, 1922

CAMP, WILMER E., Sales Engineer, General Electric Co., Sacramento, Calif.

CRITTENDEN, EUGENE C., Physicist, Acting Chief of Electrical Division, Bureau of Standards, Washington, D. C.

HARVEY, H. G., General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

HAYDEN, THOMAS J., Teacher of Practical & Applied Science, Department of Education, New York, N. Y.

LASSAFF, B. W., Section Leader, New York Edison Co., New York, N. Y.

RANKIN, HARRY M., Lighting Engineering Dept., General Electric Co., Schenectady, N. Y.

SAMPSON, EDGAR R., General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

SQUIRE, WILLIAM J., Consulting Engineer, Kansas City, Mo.

TOMPKINS, FREDERICK N., Instructor in Electrical Engineering, Brown University, Providence, R. I.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held March 13, 1922, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

CARPENTER, HENRY C., Chief Engineer, New York Telephone Co., New York, N. Y.

CHESTERMAN, FRANCIS J., Chief Engineer, Bell Telephone Co. of Pennsylvania, Philadelphia, Pa.

KITTREDGE, CARLYLE, Chief Engineer, Michigan State Telephone Co., Detroit, Mich.

WATERSON, KARL W., Assistant Chief Engineer, American Tel. & Tel. Co., New York, N. Y.

To Grade of Member

BALL, WILLIAM J., President, Tri-City Electric Co., Moline, Ill.

BLATHERWICK, A. B., Electrical Planner, Navy Yard, Puget Sound, Bremerton, Wash.

BOYER, LEE, General Manager, Consolidated Power & Light Co., Deadwood, S. D.

CARPENTER, FRANK B., Electrical Engineer, West Virginia Engineering Co., Charleston, W. Va.

EGNER, ROBERT J., Section Engineer, American Tel. & Tel. Co., New York, N. Y.

GREEN, IRVING W., Engineer, Dept. of Development & Research, American Tel. & Tel. Co., New York, N. Y.

KING, ROBERT P., Works Engineer, East Springfield Works, Westinghouse Elec. & Mfg. Co., Springfield, Mass.

LATZER, FREDERICK, Electrical Engineer, Van Wagoner Linn Construction Co., New York, N. Y.

MEYER, HANS J., President, Charles L. Pillsbury Co., Minneapolis, Minn.

SCHNABEL, JAMES F., Assistant Sales Engineer, Electric Controller & Mfg. Co., Cleveland, O.

SMITH, HAROLD R., Partner in Smith, Robinson & Co., Vancouver, B. C.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute, the list indicating the geographical district and Section in which the applicant is at present located. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before April 30, 1922.

Geographical District No. 1

Boston Section

Carothers, Fred N., Boston, Mass.
Lackie, Walter J., Boston, Mass.
O'Bryan, Francis L., (Member), Framingham, Mass.
Smith, W. Lincoln, (Member), Boston, Mass.

Connecticut Section

Bacon, Harold R., New Haven, Conn.
Bazzeghin, Fortunato, Hamden, Conn.

Lynn Section

Blake, G. Waldron, Lynn, Mass.
Campbell, Tristram J., Lynn, Mass.
Chestnut, D. Lee, Lynn, Mass.
Clements, Albert H., Lynn, Mass.
Dawson, Joseph C., Lynn, Mass.
Ellis, Ralph DeL., Lynn, Mass.
Gates, Arthur H., Lynn, Mass.
Henderson, William McC., Lynn, Mass.
Jameson, George S., W. Lynn, Mass.
Kershaw, Walter F., Lynn, Mass.
Lipson, Edward, W. Lynn, Mass.
McBride, Henry J., Lynn, Mass.
Richardson, Harvey R., W. Lynn, Mass.
Seaburg, Algodt J., Magnolia, Mass.
Sharp, Fred R., E. Saugus, Mass.
Smyser, Frederic H., W. Lynn, Mass.
Sprenger, George W., Lynn, Mass.
Sweeney, Denis, Lynn, Mass.
Sweeney, Eugene C., Lynn, Mass.

Providence Section

Ames, Alfred C., Providence, R. I.

Rochester Section

Benard, Arthur G., Victor, N. Y.
Lapp, G. W., LeRoy, N. Y.

Schenectady Section

Blincoe, Lemuel R., Schenectady, N. Y.
Elliott, Marion B., Schenectady, N. Y.
Gomer, Louis F., Victory Mills, N. Y.
Gutierrez, Miguel M., Schenectady, N. Y.
St. Clair, Harry P., Schenectady, N. Y.
Thompson, Benjamin H., Schenectady, N. Y.
Wolfertz, Edward, Acra, N. Y.

Worcester Section

Harrington, John W., Worcester, Mass.
Regan, Joseph P., Worcester, Mass.
Total 37.

Geographical District No. 2

Akron Section

Joslin, Arba V., S. Akron, Ohio

Baltimore Section

Ervine, William G., Baltimore, Md.
Gauss, Charles H., Baltimore, Md.
Mohr, Carl H., Baltimore, Md.

Cincinnati Section

Breckel, Harry F., Cincinnati, Ohio
Hauss, Albert F., Cincinnati, Ohio
Lewis, R. Arnold, Cincinnati, Ohio
Wagner, Milton H., (Fellow), Dayton, Ohio

Cleveland Section

Beach, Albert B., Cleveland, Ohio
Schroeder, Carl J., Cleveland, Ohio
Shober, Wilbur M., Cleveland, Ohio

Lehigh Valley Section

Milburn, William I., Allentown, Pa.
Schad, James H., Allentown, Pa.

Philadelphia Section

Horton, Reuben H., (Member), Philadelphia, Pa.
Watts, Myers G., Philadelphia, Pa.

Pittsburgh Section

Hixson, Arthur G., Springdale, Pa.
Keller, Edward L., Pittsburgh, Pa.
Scheer, George B., E. Pittsburgh, Pa.

Washington, D. C. Section

Bailey, William H., Washington, D. C.
Bissett, George, Washington, D. C.
Folsom, Sherman I., Washington, D. C.
Greer, Hugh D., Washington, D. C.
Halle, Simon, Washington, D. C.
Natton, Wesley L., Washington, D. C.
Nicholson, Charles J., Washington, D. C.
O'Boyle, Gardner J., Brookland, D. C.
Oldfield, Robert T., Washington, D. C.
Peers, George T., Washington, D. C.
Smirnoff, Alexander I., Washington, D. C.
Speakman, Edwin G., Jr., Washington, D. C.
Starr, James H., Washington, D. C.

Non-Section Territory

Brown, Roy A., Columbus, Ohio
Culver, Charles O., Salisbury, Md.
Frost, Lloyd W., Columbus, Ohio
Kaupp, Charles O., Williamsport, Pa.
Raney, Estell C., (Member), Columbus, Ohio
Schumacker, R. J., (Member), Marblehead, Ohio
Smith, Allan J., Columbus, Ohio
Smith, John H., (Member), Harrisburg, Pa.
Temple, John C., Columbus, Ohio
Total 40.

Geographical District No. 3

New York Section

Barnett, Walter, New York, N. Y.
Bhole, Shanker J., New York, N. Y.
Bowne, Langford J., New York, N. Y.
Casper, Louis, (Member), New York, N. Y.
Edenburg, Louis, (Member), New York, N. Y.
Eisenstadt, Maurice, Rutherford, N. J.
Erickson, Frank W., New York, N. Y.
Fetzer, Karl McA., New York, N. Y.
Fischer, August H., (Member), New York, N. Y.
Grece, Charles J., New York, N. Y.
Hahn, Harold W., New York, N. Y.
Hall, Merton C., New York, N. Y.
Hartmann, Zoltan, New York, N. Y.
Hermance, Carl H., New York, N. Y.
Holden, William H. T., New York, N. Y.
Hull, John P., New York, N. Y.
Johnson, Herbert B., New York, N. Y.
Kelley, Charles F., New York, N. Y.
Kelly, Nicholas J., New York, N. Y.
Kirk, J. Newton, New York, N. Y.
Lewis, William J., Jr., (Member), Brooklyn, N. Y.
Lucek, Charles W., New York, N. Y.
McRae, George W., (Member), New York, N. Y.
Moore, Ernest E., New York, N. Y.
Nager, Edward, New York, N. Y.
O'Connor, Charles E., New York, N. Y.
Pringle, John A., Newark, N. J.
Ringsdorf, Charles A., New York, N. Y.
Ryan, James J., Brooklyn, N. Y.
Sangree, Ernest M., New York, N. Y.
Satterthwaite, J. Paul, New York, N. Y.
Senauke, Alexander, New York, N. Y.
Shepherd, Roswell L., New York, N. Y.
Smith, Philip S., (Member), New York, N. Y.
Sparrow, Maxwell E., New York, N. Y.
Stone, George S., Dover, N. J.
Stone, William C., Jersey City, N. J.
Takagi, Moichi, New York, N. Y.
Terry, Francis M., New York, N. Y.
Van Wagner, Paul, New Brighton, N. Y.
Voyack, Frank, Long Island City, N. Y.
Wells, Loren S., (Member), New York, N. Y.
White, Charles, New York, N. Y.
Williams, Marion S., New York, N. Y.
Wilson, Guy E., New York, N. Y.
Woolsey, Clarence V., (Member), Brooklyn, N. Y.

Non-Section Territory

De Bernard, Euginir, Havana, Cuba
Sealey, Samuel A., Camaguey, Cuba
Total 48.

Geographical District No. 4

Non-Section Territory

Bell, Bennie H., New Orleans, La.
Davis, Robert V., Montgomery, Ala.
Frost, Frank G., (Member), New Orleans, La.
Keeney, John W., Norfolk, Va.
Pfleiderer, Charles A., Louisville, Ky.
Total 5.

Geographical District No. 5

Chicago Section

Burmeister, Harry W., Chicago, Ill.
Epstein, Hirsch, Chicago, Ill.

Detroit Section

Bersey, Walter S., Lansing, Mich.
Schepperly, Joseph A., Detroit, Mich.

Ft. Wayne Section

Bower, Gerald A., Ft. Wayne, Ind.
Davis, Dean W., Ft. Wayne, Ind.
Gaines, Earl L., (Member), Ft. Wayne, Ind.
Grable, Joseph P., Ft. Wayne, Ind.
Horn, George B., Ft. Wayne, Ind.
Jackson, Donald J., Ft. Wayne, Ind.
Myers, Carl M., Ft. Wayne, Ind.
Tarmon, Ray F., Ft. Wayne, Ind.

Indianapolis Section

King, Carl M., Indianapolis, Ind.

Non-Section Territory

Buckley, Willis A., South Bend, Ind.
Hutton, William T., Galena, Ill.
Van Loan, Cullen G., La Cross, Wis.
Total 16.

Geographical District No. 6

Denver Section

Fraser, Verness, Denver, Colo.
Graff, Murray G., Denver, Colo.
Hardaway, Warren D., Denver, Colo.
Huntzicker, Paul, Pueblo, Colo.
Lord, Mark G., Pueblo, Colo.
McCammon, Floyd F., Denver, Colo.
McDonald, Vernon M., Denver, Colo.
Quandt, William, Pueblo, Colo.

Minnesota Section

Anderson, George N., Minneapolis, Minn.
Total 9.

Geographical District No. 7

St. Louis Section

Crider, Ned, Webster Groves, Mo.
Jones, Walter L., Jr., St. Charles, Mo.
Total 2

Geographical District No. 8

Los Angeles Section

Charbonneau, L. Henry, Los Angeles, Cal.
Drayton, Walter, Los Angeles, Cal.
Hopper, Francis L., Pasadena, Calif.
Johnson, Verne E., San Bernardino, Cal.
Jones, Rufus G., Riverside, Cal.
Neuman, Robert, Corona, Cal.
Putnam, Arthur C., Riverside, Cal.
Wills, George M., Riverside, Cal.

San Francisco Section

Neal, D. E., San Francisco, Cal.
Seki, Riuichi, San Francisco, Cal.
Total 10.

Geographical District No. 9

Portland Section

Braun, Carl E., Camas, Wash.
Johnson, Gus A., Portland, Ore.
Seibert, H. W., Portland, Ore.

Utah Section

Brokemyr, Josef E., Salt Lake City, Utah

Non-Section Territory

Fiske, John M., Bozeman, Mont.
Stevenson, Clyde D., Wolf Creek, Mont.
Total 6.

Geographical District No. 10

Toronto Section

Chipperfield, John W., Toronto, Ont.
Dilks, Arthur G., Toronto, Ont.
Holley, Otto B., Sault Ste. Marie, Mich.
Manby, Aaron W., Niagara Falls, S. Ontario
Pullen, Frank, (Member), Toronto, Ont.
Thistlethwaite, Gordon J., Iroquois Falls, Ont.

Vancouver Section

Jenkinson, John, Vancouver, B. C.
Matkin, Gerald R., Trail, B. C.
McKnight, Robert, Britannia Beach, B. C.

Non-Section Territory

Belanger, Ernest, Grand Mere, P. Q.
Lash, Norwood M., (Member), Montreal, Que.
Total 11.
Total Applications Received 184.

FOREIGN

Braaten, Ingvald T., Christiania, Norway
Crowley, Cornelius, Queensland, Aus.
Evans, Clive W., (Member), Waratah, Tasmania
Kawashima, Chiako, Tokio, Japan
Matsuo, Sadahiro, Sukegawa, Ibaragiken, Japan
Ohya, Eishiro, Nagoya, Japan
Osborne, Willis E., Simla, India
Pearce, Stanley B., Sydney, N. S. W.
Yoshida, Reiji, Nagoya, Japan
Zwietusch, Edward O., Berlin-Charlotten, Germany
Total 10.

STUDENTS ENROLLED MARCH 17, 1922

14767 Longfellow, Charles F., Jr., Mass. Institute of Technology.
14768 Davis, Berle M., University of Arizona
14769 Coogan, Edward D., Mass. Inst. of Tech.
14770 Mayea, Lawrence E., Drexel Institute
14771 Embovitz, Alfred, New York Elec. School
14772 Van Etten, George W., Lafayette College
14773 Abaraham, Leonard G., Univ. of Illinois
14774 Carlson, Herbert N. R., Univ. of Illinois
14775 Bellenbach, Elmer R., Univ. of Illinois
14776 Trebus, Erwin H., Univ. of Wisconsin
14777 Cautchlou, William, Jr., Newark Technical School
14778 Suppers, Hobart G., Drexel Institute
14779 Saunders, John B., Queen's University
14780 Baylies, Alfred J., Drexel Institute
14781 Benjamin, Ernest C., Jr., Lafayette College
14782 Frick, Darrell C., Ohio Northern University
14783 Kenrick, Ralph S., Armour Inst. of Tech.
14784 Waver, Frank H., Armour Inst. of Tech.
14785 Schaefer, Edward J., Johns Hopkins Univ.
14786 Hensen, Carvel, Johns Hopkins University
14787 Matthews, LeRoy F., Johns Hopkins Univ.
14788 Karpf, Leon J., Brooklyn, Polytechnic Inst.
14789 Wellentin, J. Earl, University of N. Dakota
14790 Randall, Charles W., University of N. Dak.
14791 Frey, A. Page, Y. M. C. A. Technical School (Baltimore)
14792 Curry, Haskell B., Mass. Inst. of Tech.
14793 Meltvedt, Henry, Iowa State College
14794 McCreary, Harold J., Univ. of Nebraska
14795 Emch, Ronald, Ohio State University
14796 Irving, Ellery, Ohio State University
14797 Lawthers, Stanley M., Ohio State Univ.
14798 Libben, Walter F., Ohio State University
14799 Sherrard, Joe O., Ohio State University
14800 Ulm, Lorin G., Ohio State University
14801 Hoilman, Charles W., Virginia Poly. Inst.
14802 Sheppard, Hubert A., Virginia Poly. Inst.
14803 Loehr, John E., Columbia University
14804 Calloe, Merton E., Montana State College
14805 Schmidt, Herbert E., A. & M. Coll. of Tex.
14806 Lord, George C., University of Wisconsin
14807 Lloyd, Fay D., Ohio State University
14808 Barley, Leo D., Ohio State University
14809 Brown, Roy L., Ohio State University

14810 Creamer, Charles D., Ohio State University
14811 Cros, Rene L., Ohio State University
14812 Cross, Charles H., Ohio State University
14813 Dickson, John B., Jr., Ohio State Univ.
14814 Kaspar, Raymond H., Ohio State University
14815 Linxweiler, Carl J., Ohio State University
14816 Rendelesham, Rollin H., Ohio State Univ.
14817 Sheely, Robert R., Ohio State University
14818 Steffan, James C., Ohio State University
14819 Corcoran, Harry R., Case School of Applied Science.
14820 Lee, Etheridge, Univ. of North Dakota
14821 Erickson, Ellis O., Univ. of No. Dakota
14822 Stamper, Furman H., Columbia University
14823 Alderson, William T., Johns Hopkins Univ.
14824 Fee, Lawrence G., Purdue University
14825 Siekman, Philip W., Purdue University
14826 Skinner, Vernon O., Purdue University
14827 Woodling, George V., Purdue University
14828 Carter, Marion G., Purdue University
14829 Walter, Ivan V., Purdue University
14830 Thorp, Alvan A., Purdue University
14831 Papazian, Nerses, Purdue University
14832 Kurosumi, Tokuji, University of Utah
14833 Adams, Earle F., Newark Technical School
14834 Gray, Carl A., University of Kansas
14835 Appleby, Harry A., University of Kansas
14836 Matteson, Rosell C., Univ. of Nebraska
14837 Rumsey, John L., Case School of App. Sci.
14838 Toon, E. Earl, Case School of App. Science
14839 Atwood, David S., Stanford University
14840 Hudson, Carroll D., Stanford University
14841 Nef, Kenneth D., Stanford University
14842 Clark, Philip C., Stanford University
14843 Clark, George S., Stanford University
14844 Williams, Roland A., Drexel Institute
14845 Sklar, Louis, Drexel Institute
14846 Soger, Charles R., Drexel Institute
14847 Hassell, Frank W., Jr., Drexel Institute
14848 Cove, Benjamin H., Drexel Institute
14849 Abel, George W., New York Elec. School
14850 McHirron, Byron C., University of Nebr.
14851 Davis, Flavius E., Jr., Univ. of Virginia
14852 Ratcliff, Horace H., Univ. of Wisconsin
14853 Banta, Theodore C., Cornell University
14854 Robinson, Joseph L., Cornell University
14855 Kobayahsi, Teiji, Cornell University
14856 Lawrence Claude D., Cornell University
14857 Coupal, Edward T., Cornell University
14858 Haley, Hugh David, Mass. Inst. of Tech.,
14859 Pyle, Frank J., Pennsylvania State College
14860 Taubenkimel, Israel, New York Elec. Sch.
14861 Hormeling, Henry C., Univ. of Illinois
14862 Caldwell, Eugene, Ohio State University
14863 Metzger, Walter E., Ohio State University
14864 Sawyer, Robert T., Ohio State University
14865 Wolf, Alfred, Mass. Institute of Technology
14866 Lee, John A., University of Colorado
14867 Todd, Francis C., Oklahoma A. & M. Coll.
14868 Krausse, Erich P., Oklahoma A. & M. Coll.
14869 Danner, William E., Rose Poly. Institute
14870 Wilson, Carl B., Rose Poly. Institute
14871 Pittman, Sterling H., Rose Poly. Institute
14872 Wilson Hubert L., Rose Poly Institute
14873 Gruesing, John H., Rose Poly. Institute
14874 Swineford, Howard L., Virginia Poly. Inst.
14875 Frank G. Chrisman, Virginia Poly. Inst.
14876 Valentine, Haddon P., University of Wash.
14877 Foley, Leonard S., Univ. of Washington
14878 Evans, Miller, University of Washington
14879 Parr, James F., Univ. of Washington
14880 Anderson, David G., Univ. of Washington
14881 Rasmussen, Fred N., Univ. of Washington
14882 Arnold, Frederick G., Univ. of Washington
14883 Ewell, M. M., University of Washington
14884 Crump, Leonard Wade, Univ. of Wash.
14885 Jenney, Charles W., Barberton, Ohio
14886 Kradel, Frederick L., Penn. State College
14887 Lowman, Eugene A., Penn. State College
14888 Penick, Dixon B., University of Texas
14889 Spears, Albert L., New York Elec. School
14890 Larson, Linne C., Calif. Inst. of Technology
14891 Taylor, William T., Calif. Inst. of Tech.
14892 Rosseau, Leon B., Cornell University
14893 Ushioda, Seikichi, Cornell University
14894 Horne, Graham D., Cornell University
14895 McIlroy, Malcom S., Cornell University
14896 Horne, William H., Jr., Cornell University
14897 Jacobson, David, Cornell University

Total 131.

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(A list of the personnel of Institute committees may be found in the January issue of the Journal, and will be published again in the June issue.)

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(The Institute is represented on the following bodies; the names of the representatives may be found in the January issue of the Journal and will be published again in the June issue.)

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American Committee on Electrolysis
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American Engineering Standards Committee
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Franco-American Engineering Committee
John Fritz Medal Board of Award
Library Board, United Engineering Society
Electrical Committee, National Fire Protection Association
Engineering Division, National Research Council
U. S. National Committee of the International Illumination Commission
U. S. National Committee of the International Electrotechnical Commission
Commission of Washington Award

A. I. E. E. SECTIONS AND BRANCHES

A complete list of the 42 Sections and the 67 Student Branches of the Institute with the names of the chairmen and secretaries, may be found in this issue and will be published again in the June issue.

LIST OF SECTIONS

Name	Chairman	Secretary
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Atlanta	J. E. Mellett	H. N. Pye, Box 1743, Atlanta, Ga.
Baltimore	Douglas Burnett	Vern E. Alden, 1905 Lexington Building, Baltimore, Md.
Boston	Lewis W. Abbott	F. S. Dellenbaugh, M. I. T., Cambridge, Mass.
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Cincinnati	J. D. Lyon	Leo Schirtzinger, 710 Traction Bldg., Cincinnati, O.
Cleveland	I. H. Van Horn	G. B. Schneeberger, Cleveland Elec. Illuminating Co., Cleveland, O.
Connecticut	C. F. Scott	A. E. Knowlton, Dunham Laboratory, Yale University, New Haven, Conn.
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Erie	C. H. Schum	P. B. Mansfield, Lawrence Park, Erie, Pa.
Fort Wayne	R. H. Chadwick	A. B. Campbell, General Electric Co., Ft. Wayne, Ind.
Indianapolis-Lafayette	D. C. Pyke	J. W. Hannon, Telephone Bldg., Indianapolis, Ind.
Ithaca	J. G. Pertsch, Jr.	G. F. Bason, Cornell University, Ithaca, N. Y.
Kansas City	C. J. Larsen	Glenn O. Brown, K. C. Power Co., Kansas City, Mo.
Lehigh Valley	Charles Hodge	H. G. Harvey, Penna. Utilities Co., Easton, Pa.
Los Angeles	Herbert H. Cox	J. N. Kelman, 1650 Naud St., Los Angeles, Cal.
Lynn	F. J. Rudd	D. F. Smalley, General Electric Co., West Lynn, Mass.
Madison	C. B. Hayden	H. M. Crothers, Univ. of Wisconsin, Madison, Wis.
Milwaukee	F. J. Mayer	P. B. Harwood, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota	W. T. Ryan	F. A. Otto, 639 Holly Ave., St. Paul, Minn.
New York	Farley Osgood	H. A. Pratt, 165 Broadway, New York, N. Y.
Panama	R. D. Prescott	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	P. H. Chase	R. B. Mateer, Phila. Elec. Co., 1000 Chestnut St., Philadelphia, Pa.
Pittsburgh	H. W. Smith	E. C. Stone, Duquesne Light Co., 435 6th Ave., Pittsburgh, Pa.
Pittsfield	I. H. Sclater	A. C. Stevens, General Electric Co., Pittsfield, Mass.
Portland, Ore.	W. C. Heston	D. W. Proebstel, Portland Ry. Lt. & Pr. Co., Portland, Ore.
Providence	Nicholas Stahl	F. N. Tompkins, Brown Univ., Providence, R. I.
Rochester	Sidney Alling	A. M. Stetler, Aluminum Co. of America, Granite Bldg., Rochester, N. Y.
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Seattle	J. P. Growdon	E. S. Code, 1400 Alaska Bldg., Seattle, Wash.
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Toledo		Max Neuber, 1257 Fernwood Ave., Toledo, O.
Toronto	W. P. Dobson	P. A. Borden, 8 Strachan Ave., Toronto, Ont.
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Utah	P. P. Ashworth	C. R. Higson, Utah Power & Light Co., Salt Lake City, Utah
Vancouver	John R. Read	F. W. McNeill, Canadian General Elec. Co., Vancouver, B.C.
Washington, D. C.	A. R. Cheyney	W. A. E. Doying, Panama Canal Commission, Washington, D.C.
Worcester	G. M. Hardy	Dean J. Locke, 125 Salisbury St., Worcester, Mass.
Total 42		

LIST OF BRANCHES

Name and Location	Chairman	Secretary
Alabama Poly. Inst., Auburn, Ala.	V. C. McIlvaine	J. M. Dickinson
Alabama, Univ. of, University, Ala.	D. H. Davis	W. W. Bauder
Arizona, Univ. of, Tucson, Ariz.	J. Mellen	H. W. Holt
Arkansas, Univ. of, Fayetteville, Ark.	J. W. Booker	B. R. Askew
Armour Inst. of Tech., Chicago, Ill.	R. P. Burns	L. E. Grube
Brooklyn Poly. Inst., Brooklyn, N. Y.	H. Ladner	O. Engstrom
Bucknell Univ., Lewisburg, Pa.	F. T. Tingley	J. A. Ammerman
California Inst. of Tech., Pasadena, Cal.	O. R. Bulkley	L. J. Wells
California, Univ. of, Berkeley, Cal.	F. A. Polkinghorn	S. R. Ruby
Carnegie Inst. of Tech., Pittsburgh, Pa.	E. A. Brand	H. W. Bryan
Case School of Applied Science, Cleveland, O.	M. A. Hyde, Jr.	O. Henderson
Cincinnati, Univ. of, Cincinnati, O.	J. R. Petree	C. B. Hoffmann
Clarkson Coll. of Tech., Potsdam, N.Y.	R. L. Conboy	F. H. Fults
Clemson Agri. College, Clemson College, S. C.	J. R. Reardon	W. M. Clatworthy
Colorado State Agri. Coll., Ft. Collins, Colo.	P. Garrett	F. Ayres
Colorado, Univ. of, Boulder, Colo.	T. D. Sylvester	F. B. Doolittle
Cooper Union, New York	W. A. Colledge	A. L. Duna
Drexel Institute, Philadelphia, Pa.	D. Buchanan	R. E. Sidwell
Georgia School of Tech., Atlanta, Ga.	C. D. LeBey	E. V. Wallace
Iowa State College, Ames, Ia.	C. H. Hoper	G. L. Seaton
Iowa, Univ. of, Iowa City, Ia.	E. Paintin	P. F. Bowman
Kansas State College, Manhattan, Kans.	W. J. Bucklee	H. S. Nay
Kansas, Univ. of, Lawrence, Kans.	E. S. Miner	C. A. Harris
Kentucky, Univ. of, Lexington, Ky.	T. M. Riley	R. H. Craig
Lafayette College, Easton, Pa.	G. A. Moore	P. J. Brown
Lehigh Univ., South Bethlehem, Pa.	E. F. DeTurk	W. F. Tait
Lewis Institute, Chicago, Ill.	E. Millison	E. R. Lindberg
Maine, Univ. of, Orono, Me.	F. Blake	C. R. Lappin
Massachusetts Inst. of Tech., Cambridge, Mass.	L. R. Culver	L. W. Codding
Michigan Agri. Coll., East Lansing, Mich.	E. A. Pryce	J. G. Lauffer
Michigan, Univ. of, Ann Arbor, Mich.	F. D. Johnston	A. J. Martin
Milwaukee, Engg. School of, Milwaukee, Wis.	F. P. Kasparek	L. F. Berg
Minnesota, Univ. of, Minneapolis, Minn.	H. A. Dahl	E. S. Bjonerud
Missouri, Univ. of, Columbia, Mo.	A. C. Lanier	F. W. Hubbard
Montana State Coll., Bozeman, Mont.	W. W. Husemeyer	R. D. Sloan
Nebraska, Univ. of, Lincoln, Neb.	O. J. Ferguson	O. E. Edison
North Carolina State College, West Raleigh, N. C.	E. E. Inscoe	O. L. Bradshaw
North Carolina, Univ. of, Chapel Hill, N. C.	R. M. Casper	R. G. Koontz
North Dakota, Univ. of University, N. D.	E. L. Hough	S. W. Winje
Notre Dame, Univ. of, Notre Dame, Ind.	J. R. Fitzgerald	W. L. Shilts
Ohio Northern Univ., Ada, O.	L. A. Kille	I. W. Knapp
Ohio State Univ., Columbus, O.	W. M. Kellogg	O. McGinnis
Oklahoma A. & M. Coll., Stillwater, Okla.	C. S. Folk	I. T. Knight
Oklahoma, Univ. of, Norman, Okla.	W. Seifert	R. E. Thornton
Oregon Agri. Coll., Corvallis, Ore.	W. D. Olson	C. T. Hurd
Pennsylvania State College, State College, Pa.	H. F. Pearson	J. H. Warner
Pennsylvania, Univ. of, Philadelphia, Pa.	E. M. Heidelbaugh	J. B. Clothier, Jr.
Pittsburgh, Univ. of, Pittsburgh, Pa.	C. A. Anderson	A. F. Robert
Purdue Univ., Lafayette, Ind.	N. C. Pearcy	F. R. Finehout
Rensselaer Poly. Inst., Troy, N. Y.	W. J. Williams	L. S. Inskip
Rose Poly. Inst., Terre Haute, Ind.	F. M. Stone	C. B. Wilson
Rutgers College, New Brunswick, N. J.	H. Goldsmith	T. B. Brown
Southern California, Univ. of, Los Angeles, Cal.	R. H. Cockfield	E. B. Heath
Stanford Univ., Stanford University, Cal.	H. E. Becker	V. Marquis
Swarthmore Coll., Swarthmore, Pa.	S. T. McAllister	E. Palmer
Syracuse Univ., Syracuse, N. Y.	E. A. Ryan	A. P. Fugill
Texas A. & M. Coll., College Station, Tex.	H. A. Dougherty	G. A. Hollowell
Texas, Univ. of, Austin, Tex.	C. H. Marshall	F. J. Domingues
Virginia Military Inst., Lexington, Va.	W. P. Venable	R. P. Martin
Virginia Poly. Inst., Blacksburg, Va.	D. P. Minichan	T. F. Cofer
Virginia, Univ. of, University, Va.	M. H. Morgan	N. W. Brown
Washington, State Coll. of, Pullman, Wash.	E. Johnson	O. J. Ball
Washington Univ., St. Louis, Mo.	F. W. Schramm	E. H. Burgess
Washington, Univ. of, Seattle, Wash.	C. E. Allen	C. A. Brokaw
West Virginia Univ., Morgantown, W. Va.	H. Chandler	W. D. Stump
Wisconsin, Univ. of, Madison, Wis.	R. H. Herrick	J. W. Smart
Yale Univ., New Haven, Conn.	E. R. Zeitz	S. S. Bailey
Total 67		

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGS AND OTHER TRADE PUBLICATIONS

Mailed to interested readers by issuing companies.

Blower.—Leaflet. Describes "4 Cyclone Portable Blower" for cleaning electrical machinery. Chas. W. Emery & Sons, 1304 Diamond St., Philadelphia.

Molded Insulation.—Folder. Illustrating various types of insulators for line, wireless, ignition, etc. Electrose Mfg. Co., 60 Washington St., Brooklyn, N. Y.

Commutator Grinders and Slotters.—Folder. Describes "Imperial" commutator stones for grinding commutators; and tools for undercutting mica. The Martindale Electric Co., 11737 Detroit Ave., Cleveland.

Motors.—Bulletin 102, 24 pp. Direct-current motors and generators. The Ideal Elec. & Mfg. Co., Mansfield, O.

Motors.—Bulletin 103, 24 pp. Squirrel Cages and Slip Ring Induction Motors. The Ideal Elec. & Mfg. Co, Mansfield, O.

Insurance.—Folder. "Engine Insurance" describing power plant insurance. The Travelers Indemnity Co.. Hartford, Conn.

Electrical Tests.—Booklet. Describes service and fees for tests of material and apparatus. Electrical Testing Laboratories, 80th St. & East End Ave., New York.

Micrometer Indicator.—Bulletin. For measuring and checking the diameter of wire, small screw machine parts, etc. Elsee Products Corp., 280 Broadway, New York.

Automatic Stokers.—Bulletin. Describing "Type K" stoker for operating boilers ranging up to 220 h. p. at high capacity and efficiency. Combustion Engineering Corp., New York.

Motors.—Bulletin 200. Type "M. C." d-c. motors. The Marble-Card Electric Co., Gladstone, Mich.

Motors.—Bulletin 3. Type "R" repulsion induction motors. Baldor Electric Co., St. Louis.

Water Level and Valve Position Indicators.—Bulletin 43-A. Electrically operated instruments indicating level of water and valve conditions existing in remote and inaccessible points. Payne Dean Ltd., 103 Park Ave., New York.

Rheostatic Switch.—Booklet, 8 pp. Describing the "Economee" liquid resistance rheostatic switch for applying current gradually. For lighting and power. Economee Rheostatic Switch Co., 3551 No. 5th St., Philadelphia.

Fire Alarm Equipment.—Catalog 34. Describes telegraph equipment, recording instruments, call boxes, etc. Foote, Pierson & Co., Inc., 160 Duane St., New York.

Motor Generator Sets.—Bulletin 30. Illustrating installations of different types of motor generator sets. Ridgway Dynamo & Engine Co., Ridgway, Pa.

Steel Wire for Electrical Transmission.—Booklet "Double Galvanized Steel Strand and Iron Wire for Electrical Transmission and Distribution." Indiana Steel & Wire Co., Muncie, Ind.

Watthour Meters.—Bulletin 55. Describing construction, installation, testing and connections of a-c. single-phase and polyphase motors. Sangamo Electric Co., Springfield, Ill.

Instruments.—Catalog 19. Describes electrical precision instruments, laboratory accessories, etc., used in connection with heat treatment. The Pyroelectric Instrument Co., Trenton, N. J.

Lightning Protector Apparatus.—Bulletin 183, 62 pp. Describes "Keystone" expulsion type and "Garton-Daniels" arresters. Electric Service Supplies Co., Philadelphia.

Current-Limiting Reactors.—Bulletin. Designed to prevent heavy currents on short-circuits, eliminating severe mechanical stresses in connected apparatus. Westinghouse Electric & Mfg. Co., E. Pittsburgh.

Refuse Incinerators.—Booklet. 20 pp. "Refuse Collection and Disposal." Describing Balmer refuse destructor system. Electric power generating units are combined in each destructor station for the purpose of utilizing the waste heat developed. Balmer Corporation, 150 Nassau St., New York.

Carbon Electrodes.—Second edition "The Carbon Electrode," book, 80 pp., illustrated, leather bound. Outlines the history of the electrode and the electric furnace; describes process of electrode manufacture and most economical application. Illustrates by diagrams the transformer connections of various types of electric furnaces. National Carbon Co., 30 E. 42nd St., New York.

Controllers.—A handbook, (30 pp.) on controllers for electric motors has been issued by the Electric Power Club. Besides explaining in simple language the words which do not appear in dictionaries, it gives the meaning of terms with which users of electrical apparatus should be familiar. The handbook may be obtained from leading manufacturers of electrical power and control apparatus, or from S. N. Clarkson, Executive Secretary, Electric Power Club, 1017 Olive St., St. Louis.

CHANGES IN THE INDUSTRY

Irvington Varnish & Insulator Co., Irvington, N. J. The ownership of this corporation has changed hands, all of the common stock having been acquired by a syndicate composed of William F. Hoffman, Arthur E. Jones and Carl Egner. The officers are now as follows: Chairman of the Board of Directors, William F. Hoffman; President, Arthur E. Jones; Vice-President, William F. Hoffman; Vice-President, Arthur E. Jones; Secretary, Carl Egner. D. Frederick Burnett remains as Treasurer of the Company, a position he has held for the past two years. Both Mr. Burnett and Mr. Young were members of the former directorate.

National Carbon Co.—American Eveready Works. The Sales and Accounting Divisions of the National Carbon Co., Inc. (Cleveland) and the American Eveready Works of the National Carbon Company will be consolidated with offices at Long Island City, N. Y. The new organization will be known as the National Carbon Co., Inc. The general offices of the Columbia products division will also be moved from Cleveland to Long Island City. Warehouses and district sales offices will be maintained at Chicago, Cleveland, Kansas City, Atlanta and Long Island City.

The Pelton Water Wheel Co.—Wm. Cramp & Sons Ship & Engine Building Co.—The plant and interests of the Pelton Water Wheel Company, of San Francisco and New York, have been acquired by the William Cramp & Sons Ship & Engine Building Company, of Philadelphia. The Pelton Water Wheel Company will retain its old corporate name and no material changes of policy are contemplated, but new officers have been chosen, as follows: Mr. H. B. Taylor (Vice-President of the William Cramp & Sons Ship & Engine Building Company), President; Mr. Ely C. Hutchinson (formerly Chief Engineer of The Pelton Water Wheel Company), Vice-President and General Manager; Mr. William M. Moody, Second Vice-President. This merger combines two of the oldest and most prominent manufacturers of hydraulic prime movers. The Pelton Company's most important work has been in the building of impulse wheels and high-head reaction turbines, while the I. P. Morris Department of the Cramp Company has been noted mainly for large low-head reaction units.